

MONETARY POLICY, ASSET MARKETS AND BUSINESS CYCLES

*An assessment of Haavelmo's short-run
macroeconomic model*

ALMA KAJTAZ



THESIS FOR THE DEGREE
MASTER IN ECONOMIC THEORY AND ECONOMETRICS

DEPARTMENT OF ECONOMICS
UNIVERSITY OF OSLO

NOVEMBER 2010

Monetary policy, asset markets and business cycles

An assessment of Haavelmo's short-run macroeconomic model

© Alma Kajtaz

2010

Monetary policy, asset markets and business cycles

Alma Kajtaz

<http://www.duo.uio.no/>

Trykk: Reprosentralen, Universitetet i Oslo

Abstract

The model of portfolio management presented in Haavelmo (1969) is the point of departure for this thesis, presented in chapter 2. This model introduces a fundamental link between asset markets and the real economy by allowing real capital to serve the role of both an asset and a factor of production. This link makes the model suitable for representing the fragility of the real economy to imbalances in asset markets. In particular, the model introduces the following paradox: Any attempt to control interest rates in order to achieve a monetary goal such as stabilization of CPI inflation may disrupt the equilibrium of asset markets, and in that way lead to changes in macroeconomic relationships that may be difficult to chart in real time. Thereby “predictability” of the macroeconomy, which is essential as an aid to policy decisions, may be lost.

Preface

The process of writing this thesis has been more educational and interesting than I could ever have hoped for, for which my supervisor, Ragnar Nymoen, has to be honored. First, for bringing an interesting macroeconomic model by Nobel laureate Trygve Haavelmo to my attention, second, for his extraordinary ability to explain macroeconomic and econometric phenomena, and last but not least, for his commitment and dedication to the role of a supervisor. Completion of this thesis would not have been possible without his help, for which I will be forever grateful.

Any remaining inaccuracies are mine, and mine alone.

Contents

1	Introduction	1
2	Imbalances in asset markets	3
2.1	The role of producers.....	3
2.2	The portfolio allocation decision.....	4
2.3	The effect of monetary regimes.....	8
3	Open economy.....	12
3.1	The portfolio allocation decision including the market for foreign exchange	12
3.2	Specifying the monetary - and exchange rate regimes.....	20
4	Some remarks on the empirical relevance and “testability” of the theory	22
5	Monetary policy in the U.S. since the foundation of the Federal Reserve System.....	25
6	Descriptive statistics and econometrics tests	36
6.1	Automatic model selection	36
6.2	Trends and breaks in the US federal funds effective rate.....	39
6.3	Housing prices and the interest rate.....	43
6.4	Private nonresidential fixed investment	50
7	Conclusion.....	56
	References	57
	Appendix A: Documentation of data	58
	Appendix B: Explanation of trends and diagnostic tests.....	61

List of tables

Table 2.1: Balance sheet of the private sector.....	4
Table 2.2: Balance sheet of the central bank.....	5
Table 3.1: Financial balances	13
Table 6.1: Structural breaks in the federal funds effective rate, FEDFUNDS	41
Table 6.2: Estimation results for the models chosen by <i>Autometrics</i> , housing prices.	48
Table 6.3: Estimation results for the models selected by <i>Autometrics</i> , investment rate.	53

List of figures

Figure 5.1: Plot of the federal funds effective rate and CPI inflation.	29
Figure 5.2: Timeline of monetary policy targets.....	35
Figure 6.1: An example of how <i>Autometrics</i> works.....	38
Figure 6.2: The FEDFUNDS, its long - run mean and structural breaks.	43

Figure 6.3: Four alternative time series of LHPI as deviation from trend.	44
Figure 6.4: Cross correlation function between FEDFUNDS and LHPI.	45
Figure 6.5: Scatter plot of FEDFUNDS and LHPI with 10 sequential regression lines.	46
Figure 6.6: Temporary change in the FEDFUNDS, effect on LHPI, deterministic trend.	49
Figure 6.7: Temporary change in the FEDFUNDS, effect on LHPIhp, hp-trend.	49
Figure 6.8: Actual value of DLHPI against its fitted counterpart.	50
Figure 6.9: Cross correlation function between L(PNFI/GDP) and the FEDFUNDS.	52
Figure 6.10: Scatter plot of the FEDFUNDS and L(PNFI/GDP), with regression lines.	52
Figure 6.11: Temporary change in the FEDFUNDS, effect on L(PNFI/GDP), determ. trend.	54
Figure 6.12: Temporary change in the FEDFUNDS, effect on L(PNFI/GDP)hp, hp-trend. ...	54

1 Introduction

How was it possible not to foresee the financial crisis of 2007, when there was a development in important economic indicators suspiciously similar to those witnessed prior to previous economic crises, see Reinhart and Rogoff (2008)? A model presented in Haavelmo (1969), also referred to as Haavelmo's model in the forthcoming, is relevant for this question because it theoretically disputes the claim often made in textbook models and in much policy advice, namely that there is a relatively strong and well defined functional relationship between the interest rate as the monetary policy instrument and the macroeconomic outcome. Haavelmo's theoretical model instead suggests that the functional relationship is far more complicated than one might first believe, and that this makes predictions much harder than proponents of straightforward causes and effects are willing to admit. In particular, Haavelmo seems to suggest that this is the price to be paid when interest rates are controlled in order to achieve narrow monetary policy targets.

The model of portfolio management presented in Haavelmo (1969) is the point of departure for this thesis, presented in chapter 2. This model introduces a fundamental link between asset markets and the real economy by allowing real capital to serve the role of both an asset and a factor of production. This link makes the model suitable for representing the fragility of the real economy to imbalances in asset markets. In particular, the model introduces the following paradox: Any attempt to control interest rates in order to achieve a monetary goal such as stabilization of CPI inflation may disrupt the equilibrium of asset markets, and in that way lead to changes in macroeconomic relationships that may be difficult to chart in real time. Thereby "predictability" of the macroeconomy, which is essential as an aid to policy decisions, may be lost.

Although filled with insights, there is no doubt that Haavelmo's model is full of simplifications, one of them being that the considerations are restricted to the closed economy. A natural extension is to include a foreign sector, which is done in chapter 3. This is done in order to make the model more relevant for applications, since real economies after all are open economies, large domestic markets withstanding. Another motivation for this chapter is theoretical: We would like to know whether the logical property mentioned above (and which is due to certain over determination) "survives" in an open –economy version of the model. The answer, I find, is yes. The same logical property is also manifest in the open

economy model. Still, the model is based on simplifying, *ceteris paribus*, conditions and empirical counterparts to the theoretical conclusions cannot be expected to be clear cut in real life. A brief discussion of bridging from theory to data is given in chapter 4.

The theory proposed by Haavelmo will be tested on US data, but before embarking on that, a presentation of monetary policy in the U.S. since the foundation of the Federal Reserve System will be given in chapter 5. As will be evident, interest rates have been either an important instrument to achieve monetary policy goals or a target in themselves. Accordingly, the U.S. is well suited for testing the implications of the theoretical model.

In chapter 6, a presentation of descriptive statistics and econometrics tests is given. A striking pattern appears: Housing prices and private nonresidential investment are both affected, but not easily controlled, by changes in the federal funds effective rate.

All estimations and productions of graphs in this thesis have been performed by use of OxMetrics 6 and PcGive13.

2 Imbalances in asset markets

Our model-economy will consist of a private sector, including the government and private capital owners, a central bank, and a sector of producers. What distinguishes our model from those usually considered is that real capital is considered both as a factor of production and as an asset. In particular, the private sector is assumed to own real capital which it can rent out to producers. The presentation builds on Haavelmo (1969), Haavelmo (1987) and Bårdsen and Nymoen (2001), but hopefully the more detailed discussion of the behavior of producers and portfolio managers will be found useful for the extensions and use of the model in the sections that follow later in the thesis.

2.1 The role of producers

Suppose there are a large number of homogeneous producers taking all prices as given and producing one single good. For simplicity, we consider the case in which there are only two factors of production; real capital, symbolized by K , and labor, symbolized by N . The model is meant to be relevant for short-run analysis and therefore the supply of capital is assumed to be fixed at some level K^S , which will also be demanded by producers. Let Y symbolize the quantity of output. Then the production function for a representative producer can be written as:

$$Y = f(N, K^S)$$

for which standard assumptions known from production theory apply.¹ Let P be the price level and w the wage rate.² Further, let us define the real rate of return on real capital, r_K , as:

$$(2.1) \quad \frac{\partial f(N^S, K^S)}{\partial K^S} \equiv r_K$$

where N^S denotes the supply of labor, which will also be fixed due to the time perspective of our model. The real rate of return is what producers have to pay for each unit of real capital they borrow from capital owners. Then, the profit-maximization problem facing the representative producer can be written as:

¹ That is, positive, but declining marginal product of both factors of production.

² We assume that the price of real capital and the final good is the same.

$$\begin{aligned} \max_N \pi &= PY - r_K PK - wN \\ \text{s.t. } Y &= f(N, K^S) \end{aligned}$$

of which the first-order condition is:

$$(2.2) \quad \frac{\partial f(N^*, K^S)}{\partial N} = \frac{w}{P}$$

This is a well-known optimality condition saying, slightly rewritten above, that the amount used of a factor should equate its marginal revenue to its marginal cost for resources to be used in their most efficient way.

2.2 The portfolio allocation decision

Let us start by introducing the following variables:

M = money held by the private sector

L_B = net lending by banks, deducting all interest bearing deposits and bonds

PK^S = value of the stock of real capital

W = total wealth

Making use of these the following two balance sheets may be presented:

Table 2.1: Balance sheet of the private sector

Assets	Liabilities
PK^S	L_B
M	Balance = W

Table 2.2: Balance sheet of the central bank

Assets	Liabilities
L_B	M
	Balance = 0

Even though bonds are not explicitly represented on the above balance sheets, they are included when we define L_B quite broadly. Therefore bonds, the stock of bonds, can be thought to be a negative term in L_B . The same line of thought applies for deposits. Thus, the private sector has the choice between holding money, investing in real capital, making deposits in the Central Bank, and buying bonds. To carry out some of these investments borrowing from the Central Bank may be required, and if these loans are larger than the sum of the value of bonds and deposits, the private sectors will have created itself a liability, in which case L_B will be positive. The size of each component on the private sector's balance sheet will, amongst other things, depend on the real rate of return on real capital, r_K , and the real lending rate on loans, r , referred to as the real interest rate from now on.

From the above presentation the following question may appear: Since money yields no positive return, why would the private sector have incentives holding it, when a positive return from investments in real capital is available? The answer is: If money is not held, liquidity shocks could force the private sector to liquidate long-term investments, as investments in real capital usually are, of which the return would be negative.

Suppose that the utility function of the private sector is given by:

$$U\left(K, \frac{M}{P}, \frac{L_B}{P} : \frac{W}{P}, r, r_K, Y\right)$$

where real values of the assets and liabilities are included in order to account for money illusion. The private sector's objective will be to choose the value of its assets and liabilities in such a way that utility is maximized, taking the variables appearing behind the colon in the above utility function as given. However, as is usual, the utility maximization will be constrained. First, there will be a budget constraint:

$$(2.3) \quad PK^S + M - L_B = W$$

where wealth W is assumed to be fixed due to the short time perspective in our model. Second, two more conditions will constrain maximization, namely two market-clearing conditions:

$$(2.4) \quad M = L_B$$

$$(2.5) \quad PK^S = W$$

The first, that is (2.4), states that market clearing implies that the money stock is just as large as net lending. Thus for the money stock to increase net lending has to increase as well, which seems reasonable, as an increase in net lending implies that deposits are withdrawn or bonds sold, and hence the money stock held by the private sector increased. The latter, that is (2.5), explicitly states that the private sector is the only one having owner rights, and thus that its net wealth cannot be anything other than the market value of real capital.

The above- stated maximization problem gives rise to the following demand functions for the private sector:

$$(2.6) \quad K^* = D_K \left(\frac{W}{P}, r_K, r, Y \right)$$

$$(2.7) \quad \left(\frac{M}{P} \right)^* = D_M \left(\frac{W}{P}, r_K, r, Y \right)$$

$$(2.8) \quad \left(\frac{L_B}{P} \right)^* = D_{L_B} \left(\frac{W}{P}, r_K, r, Y \right)$$

Although the model is very generally formulated, it is possible to comment on the partial derivatives of the various demand functions. As wealth increases, which is an indication of the private sector getting richer, it would like to increase its assets and reduce its liabilities. If the real rate of return on real capital increases, i.e. if r_K increases, investing in real capital is more profitable and thus K^* is likely to increase. What happens to the money stock (and thus lending) is uncertain. On one hand, a higher r_K implies that holding money becomes more expensive as compared to the alternative, while on the other hand it implies that borrowing in

order to invest in real capital is more profitable. Which effect will dominate is not possible to say from a purely theoretical point of view. Next, if the real interest rate, r , increases, all the items on the private sector's balance will be reduced as borrowing and thus investments in real capital will be made more expensive and saving more profitable. If the economic activity in the economy increases, captured by an increase in production Y , we will have the opposite effect of the one just mentioned; all the items on the private sector's balance sheet will increase.

Taking stock, the equations of our model are:

$$(2.2) \quad \frac{\partial f(N^*, K^S)}{\partial N} = \frac{w}{P}$$

$$(2.3) \quad PK^S + M - L_B = W$$

$$(2.4) \quad M = L_B$$

$$(2.5) \quad PK^S = W$$

$$(2.6) \quad K^* = D_K \left(\frac{W}{P}, r_K, r, Y \right)$$

$$(2.7) \quad \left(\frac{M}{P} \right)^* = D_M \left(\frac{W}{P}, r_K, r, Y \right)$$

$$(2.8) \quad \left(\frac{L_B}{P} \right)^* = D_{L_B} \left(\frac{W}{P}, r_K, r, Y \right)$$

In order to close the model, the following three equilibrium conditions, for the labor- real capital and money market, respectively, have to be included:

$$(2.9) \quad N^* = N^S$$

$$(2.10) \quad K^* = K^S$$

$$(2.11) \quad \left(\frac{M}{P} \right)^* = \left(\frac{M}{P} \right)^S$$

Hence, our model consists of 10 equations, but only 8 of them independent. Adding (2.4) and (2.5) gives (2.3). Further, either of the equations (2.6) – (2.8) follow from the other two and (2.3). Based on this I choose to leave out equations (2.5) and (2.7) in the following.

Let us first have a look at the labor market. In this case we have two equations; (2.2) and (2.9), to solve for two variables; N^* and w . Specifically, N^* is determined by (2.9) and w by (2.2), the latter because P is assumed to be exogenous.

Next, let us have a look at the capital market. We are left with 6 equations. The number of equations may be reduced by inserting for W from the solution of (2.3) into all the others. Then our model of the capital market will be:

$$(2.4) \quad M^S = L_B$$

$$(2.6)' \quad K^* = D_K(K^S, r_K, r, Y)$$

$$(2.7)' \quad \left(\frac{M}{P}\right)^* = D_M(K^S, r_K, r, Y)$$

$$(2.10) \quad K^* = K^S$$

$$(2.11) \quad \left(\frac{M}{P}\right)^* = \left(\frac{M}{P}\right)^S$$

We are interested in classifying the variables in our model. Whether r is endogenous or exogenous will depend on how the monetary regime is specified, but the classification of the other variables will be independent of this. In particular, variables always exogenous are: P, Y, r_K and K^S , and those always endogenous are: K^*, M^*, M^S and L_B . Hence both M^* and M^S will be considered endogenous, which illustrates that the role of the central bank is to provide the economy with liquidity. As already indicated, the specification of the monetary regime will affect our model, but in what way?

2.3 The effect of monetary regimes

Suppose first that the interest rate is determined in the money market. In this case r will be endogenous and we will have 5 equations to determine 5 variables. In particular, K^* will

follow from (2.10). Then, r will be the only endogenous variable in equation (2.6)', which will give us the solution of r as a function of the exogenous variables. In particular, let this value of r be denoted by \bar{r} . Expressed formally:

$$(2.12) \quad r = \bar{r} = h(r_K^+, K^-, P, Y)$$

Inserting in (2.7)', M^* follows, which can be used in (2.11) to determine M^S . Then, L_B will follow from (2.4). Hence, the value that the real lending rate takes on in this case, \bar{r} , ensures that the asset market is in equilibrium. At this rate, the private sector will not prefer holding financial assets to real capital, and thus the law of indifference will hold in the asset market.

It is important to comment on the signs of the partial derivatives of the h -function. As the real rate of return on real capital increases the private sector will have stronger incentives investing in real capital, and will thus be willing to pay a higher interest rate in order to obtain a loan, which may be required for an investment to be realized. If the supply of real capital increases the marginal product of real capital will be reduced, and we can see from equation (2.1) that the real rate of return on real capital will be reduced as well. Thus the private sector will no longer be willing to pay as large an interest rate as earlier in order to carry out an investment in real capital. Further, when the price level increases, the real interest rate will be reduced, being a well-established relationship. Finally, to see how Y affects the lending rate, an additional assumption is needed, namely that the marginal product of real capital is decreasing in Y .³ Hence the effect of an increase in Y will be the opposite of that when the real rate of return to real capital increases; there will be a reduction in the real interest rate.

Next, suppose that the central bank sets the interest rate prevailing in the money market. In this case r will be exogenous and our model leaves us with 5 independent equations to determine 4 variables. Hence we have fewer endogenous variables than equations, and there is no guarantee that a unique value of each endogenous variable will be obtained. In particular, K^* may be determined both in (2.6)' and (2.10), and only by coincidence will the two values obtained fall together. Or, to put it another way, assuming that (2.10) holds, (2.6)' will consist only of exogenous variables and hence there is no guarantee that the value on the left-hand

³ Such an assumption is plausible if we assume that labor and real capital are technical complements. Then, whenever Y increases, so would both the factors of production and hence the marginal product of real capital would be reduced, as technical complementarity implies that it will be decreasing both in own and the other factor.

side equals that on the right-hand-side. However, one way in which this can happen (or equivalently that the same solution of K^* is obtained both from (2.5)' and (2.10)) is if the real rate of return takes a certain value, $\overline{r_K}$. Specifically, the law of indifference will hold if:

$$(2.13) \quad r_K = \overline{r_K} = g(r_+, K_-^s, P, Y_-)$$

Hence the rate of return on real capital has to be of a certain size in order for the private sector to be indifferent between holding financial assets and real capital. But then, only by coincidence will this rate be equal to the marginal product of real capital. In other words, there is no guarantee that the real rate of return ensuring that the law of indifference holds in the asset market equals the marginal product of real capital. More specifically, one of the following three situations will occur:

$$(a) \quad \frac{\partial f(N^s, K^s)}{\partial K^s} > \overline{r_K}$$

$$(b) \quad \frac{\partial f(N^s, K^s)}{\partial K^s} = \overline{r_K}$$

$$(c) \quad \frac{\partial f(N^s, K^s)}{\partial K^s} < \overline{r_K}$$

Haavelmo referred to case (b) as the classical case, which will hold in the regime where the interest rate is determined in the money market. However, once the interest rate serves as an instrument for the conduct of monetary policy, this condition can no longer be expected to represent a stable relationship. This is seen by the following thought experiment: Suppose that the interest rate is held constant (by the central bank) and that the stock of real capital (and thus wealth) increases as a result of investment activity. Then it is apparent from (2.1) that production Y will increase, from which increased economic activity and thus inflation will follow. Looking back at (2.13) we see that r_K will be affected by these changes. Only by coincidence will this change follow the development of the marginal product of real capital, which will be reduced since production has increased. Hence only sheer luck can ensure that the economy remains in the equilibrium situation characterized by (b).

In case (a) the real rate of return on real capital is less than its marginal product. Hence producers have to pay a lower price to rent one unit of real capital from the private sector, measured in units of the final good, than what they are able to produce. Then it is not surprising that their demand for real capital will increase and so will production and inflation. The increase in Y might result in the marginal product of real capital being reduced, which will have a stabilizing effect.

In case (c) the marginal product of capital will be smaller than its real rate of return. Producers would then immediately want to get rid of the real capital they are already renting, which will not be possible since real capital only can be reduced through depreciation, and that gradually. The investment activity will be close to zero, and production will fall, from which an increase in the marginal product of real capital may occur, having a stabilizing effect. However, also the real rate of return on real capital will be affected by these changes, in particular, it is expected to increase, implying that this situation may be rather long-lasting.

So, what is the main implication of the above analysis? The answer seems to be that if the goal of the monetary authority is to stabilize economic activity it should aspire to set the interest rate as close as possible to that ensuring that the law of indifference holds in the asset market. Otherwise there will be large and unpredictable movements in prices and/or quantities in this market, in particular, which will almost certainly lead to business cycles (“busts” and “booms”) also in the overall economy. One practical solution might be to say that asset prices must be of primary concern when the central bank sets the interest rate (if that regime is chosen).

Taken at face value, this conclusion runs “against the grain” of modern thinking of monetary policy, flexible inflation targeting specifically. In that regime the nominal interest rate is fixed by the central bank, with the purpose of stabilizing the economy, and, at least until lately, the credo has been that the central bank should consider the dynamics of the overall price level (through monitoring CPI inflation), with no systematic regard to capital market prices.

3 Open economy

Although filled with insights, there is no doubt that Haavelmo's model is full of simplifications, one of them being that the considerations are restricted to the closed economy. A natural extension is then to include a foreign sector. This is done in order to make the model more relevant for applications, since real economies after all are open economies, large domestic markets withstanding. Another motivation for this chapter is theoretical: We would like to know whether the logical property mentioned above (and which is due to a certain over determination) "survives" in an open economy - version of the model.

3.1 The portfolio allocation decision including the market for foreign exchange

Following Rødseth (2000), suppose that only two countries exist in our economy: Norway (domestic) and the USA (foreign). For the Norwegian economy we will make a distinction between the private sector, including private capital owners, and the government sector, including both the government and the central bank. For the US economy no such distinction will exist and we will simply refer to it as the "foreign sector". Norwegian investors are assumed to have the opportunity to invest in both NOK and USD assets, but cannot hold USD. U.S. investors, on the other hand, are restricted to invest only in USD assets and hold USD.

Table 3.1 gives a presentation of each sector's assets, where we assume that the supply of real capital in both Norway and the U.S is given, respectively at levels K^S and K_*^S , and refer to real capital in Norway (the USA) as domestic (foreign) real capital. Notice that in the below presentation of balances USD is not included as an asset in itself. One might immediately think that this is a drawback of our model, but before concluding, let us have a closer look at the specifications and assumptions made earlier. Recall that domestic residents are assumed not to hold foreign money. Further, notice that for the foreign sector we do not operate with a distinction between the private sector, the sector demanding money, and the government sector, the sector supplying money. Hence inclusion of USD money in the balance of the foreign sector will not affect the sector's net assets, and therefore such an inclusion is not made.

Table 3.1: Financial balances

Asset	Private sector	Government sector	Foreign sector	Sum
NOK	M	-M	0	0
NOK bonds	B	-B	0	0
Domestic real capital	K_p	K_g	0	K^s
USD bonds	F_p	F_g	F_*	0
Foreign real capital	K_{p*}	0	K_*	K_*^s

Let E symbolize the exchange rate; the price per unit of USD measured in units of NOK, and P the price of domestic real capital. Then each sector's net assets, denominated in the currency of the country in which the sector is resident, will be:

The private sector:
$$M + B + EF_p + PK_p + EP_*K_{p*}$$

The government sector:
$$EF_g - M - B + PK_g$$

The foreign sector:
$$F_* + P_*K_*$$

Note that the following assumption is implicit: real capital is not mobile. Hence the market value of real capital in Norway is in domestic prices, even though the price of real capital in the U.S. may be higher. Thus we assume that purchasing power parity (PPP) does not hold.

From the net assets we define the real wealth of each sector. Specifically, for the private and domestic sector, we get, respectively:

$$(3.1) \quad \frac{B + EF_p}{P} + \frac{M}{P} + K_p + \frac{EP_*}{P}K_{p*} = W_p$$

$$(3.2) \quad \frac{EF_g - M - B}{P} + K_g = W_g$$

Before turning to the foreign sector's definition of real wealth, let us have a quick glance back at our model of the closed economy. Recall the definition (slightly rewritten) of the wealth of the private sector and the central bank, respectively:

$$PK + M - L_B = W$$

$$L_B - M = W_B$$

where the private sector included both private capital owners and the government. In order to have the same definition of sectors for both model- economies, rewrite the private sector's wealth as:

$$P(K_p + K_g) + M - L_B = W$$

Remember that both deposits and bonds were included in L_B . Knowing that both are risk free and interest bearing we may consider them equivalent, and denote them by B . Also assume that there is no lending, L . From these assumptions we get

$$L_B = L - (bonds + deposits) = -B$$

If we make use of this and redefine the government sector to include both the government and the central bank, in accordance with the open economy definition, real wealth of the private and the government sector when we consider a closed economy may be expressed as, respectively:

$$K_p + \frac{M}{P} + \frac{B}{P} = \frac{W}{P} = W_p^c$$

$$K_g - \frac{M + B}{P} = \frac{W_B}{P} = W_g^c$$

Comparing to the expressions for real wealth in the open economy, that is (3.1) and (3.2), respectively, it is clear that the difference lies in the opportunity to invest in USD assets, giving domestic residents the chance to increase their wealth.

Returning to our model of the open economy, the real wealth of the foreign sector is given by:

$$(3.3) \quad \frac{F_*}{P_*} + K_* = W_*$$

Suppose that the period we are considering is so short that there is no room for wealth accumulation. If we denote initial values by the subscript 0, the absence of wealth accumulation for each sector may be expressed by:

$$\text{The private sector:} \quad M + B + EF_p + PK_p + EP_*K_{p*} = M_0 + B_0 + EF_{p0} + PK_{p0} + EP_*K_{p*0}$$

$$\text{The government sector:} \quad EF_g - M - B + PK_g = EF_{g0} - M_0 - B_0 + PK_{g0}$$

$$\text{The foreign sector:} \quad F_* + P_*K_* = F_{*0} + P_*K_{*0}$$

Next, let us have a closer look at the market for foreign exchange, and start by introducing some new variables, following Rødseth (2000):⁴

i = the NOK rate of interest

i_* = the USD rate of interest

$$e = e(E) = \frac{dE}{dt} / E, \text{ is the rate of depreciation}$$

where t denotes time.

Whenever e is larger than 0 the NOK has depreciated, and thus more NOK have to be given in exchange for one USD. On the contrary, a value of e smaller than 0 indicates that the NOK has appreciated; fewer kroner have to be given in exchange for one USD.

Recall that the private sector can invest both in USD and NOK bonds. The rate of return on investments in NOK bonds will be i , while for investments in USD bonds it may be different from i_* , all depending on movements in the exchange rate. In particular, the rate of return on investments in USD bonds will be $i_* + e(E)$. To fully understand why, let us have a look at an example: Suppose that a domestic investor buys USD bonds on which the interest rate is 0 (which is equivalent to buying USD). Even though the interest rate is 0 there will be a

⁴ The depreciation rate could also be specified as a function of both E and Z , $e(E, Z)$, Z symbolizing shocks that might affect it. As such shocks will not affect the determination of the model let us simply leave them out.

positive rate of return on this investment whenever the USD appreciates. In particular, suppose that E is 6 at the time the domestic investor buys USD bonds, but when he wants to sell them E has increased to 8. Thus, an investment of 6 NOK in USD bonds at t will give 8 NOK at $t+1$, and thus rate of return on the USD bond will be $(8-6)/6 = 1/3$. Note that this is nothing else but the depreciation rate defined earlier, making it an essential part of the rate of return on investments in USD bonds.

The private sector is assumed to always invest in those bonds giving the highest rate of return. As the size of this variable cannot be known with certainty, the private sector has to base its investment decision on the expected rate of return, which will be a function of the expected rate of depreciation, denoted by $e_e(E)$. Assuming that expectations are identical across investors, we will have perfect capital mobility between currencies. Then, the only way in which the market for foreign exchange will be in equilibrium is if the following condition holds:

$$i = i_* + e_e(E)$$

which says that, the expected rate of return by investing in bonds should be the same regardless of whether the investment is made in NOK or USD bonds. When this condition holds we will have uncovered interest rate parity, (UIP). “Uncovered” refers to the fact that the risk carried by investors, as their expectations of the depreciation rate may differ substantially from those realized, is not accounted for.

With perfect capital mobility (disregarding risk, transaction costs and heterogeneous expectations amongst investors, to mention a few) USD and NOK bonds will be considered as equivalent. For there to exist no arbitrage opportunities their expected rate of return has to be the same, and thus separate demand functions for the private sector’s demand for USD and NOK bonds will not exist; rather we will have a condition for uncovered interest rate parity.

Recall that the foreign sector is restricted to invest only in USD asset, which makes it plausible to assume that its demand for real capital is given by:

$$K_*^* = \kappa(\underset{-}{r_*}, \underset{+}{r_{K_*}}, \underset{+}{W_*})$$

where r_* is the real rate of interest in the foreign sector (as bonds are risk free this will also be the real rate of return on USD bonds), and r_{K*} the real rate of return on USD real capital. The signs below each of the right hand side variables in the above expression indicate the direction of the respective partial effects on the foreign sector's demand for foreign real capital: A higher US real interest rate implies that buying USD bonds has become more attractive for US investors, and thus their demand for foreign real capital will be reduced. When the real rate of return on foreign real capital increases, we assume that investing in foreign real capital will be more attractive for US residents. Finally, the demand for foreign real capital is increasing in wealth, as US investors in this case have become richer and would like to increase the size of at least one (assuming that real capital is one of these), or even both their assets.

When it comes to the private sector we need to recall that it can invest both in foreign and domestic real capital, and thus its demand for domestic real capital will be:

$$K_p^* = k(r, r_K, r_*, r_{K*} W_p)$$

$\begin{matrix} & - & & + & + & - & + \\ & \text{below} & & \text{above} & \text{above} & \text{below} & \text{above} \end{matrix}$

where r is the real rate of interest (as bonds are risk free this will also be real rate of return on bonds) in Norway, and r_K the real rate of return on domestic real capital. Again, the signs below each of the right hand side variables in the above expression indicate the direction of the partial effects on the demand for domestic real capital by the private sector: For the three variables r , r_K and W_P , the same reason of thought applies as for the analysis performed for the foreign sector's demand for foreign real capital. For the other two we reason as follows. The larger the real interest rate in the USA, the less attractive it is for domestic residents to invest in foreign real capital. Rather, it will be desirable to invest in USD bonds. Also, the larger the real rate of return on foreign real capital, the more attractive it is to invest in foreign real capital as compared to domestic real capital.

As already mentioned, no separate demand functions apply for the private sector's demand for USD and NOK bonds, but we will assume that it always invests a share of its wealth in bonds, in particular:

$$\frac{B + EF_p}{P} = \frac{B_0 + EF_{p0}}{P}$$

Further, we introduce the following demand function for NOK:

$$\frac{M}{P} = m(i, Y)$$

where Y denotes income. We assume that as the interest rate on NOK bonds increases it becomes less attractive to hold money, while as income increases it becomes more attractive to hold money. The reason for the latter is that as income increases so will the overall levels of transactions in the economy, at which point holding money will be profitable, since it is the most liquid asset.

Combining these the private sector's demand for foreign real capital may be expressed as:

$$K_{p*}^* = W_p - \frac{B_0 + EF_{p0}}{P} - m(i, Y) - k(r, r_K, r_*, r_{K*}, W_p)$$

Taking stock, the equations of our model are:

$$(3.1) \quad W_p = \frac{B_0 + EF_{p0} + M_0}{P} + K_{p0} + \frac{EP_*}{P} K_{p*0}$$

$$(3.2) \quad W_g = \frac{-B_0 + EF_{g0} - M_0}{P} + K_{g0}$$

$$(3.3) \quad W_* = \frac{F_{*0}}{P_{*0}} + K_{*0}$$

$$(3.4) \quad i = i_* + e_e(E)$$

$$(3.5) \quad \frac{M}{P} = m(i, Y)$$

$$(3.6) \quad K_p^* = k(r, r_K, r_*, r_{K*}, W_p)$$

$$(3.7) \quad K_{p*}^* = W_p - \frac{B_0 + EF_{p0}}{P} - m(i, Y) - k(r, r_K, r_*, r_{K*}, W_p)$$

$$(3.8) \quad K_*^* = \kappa(r_*, r_{K*}, W_*)$$

$$(3.9) \quad r = i - \pi_e$$

$$(3.10) \quad K_p^* + K_g = K^S$$

$$(3.11) \quad K_{p*}^* + K_*^* = K_*^S$$

As can be seen from the above presentation our model includes 11 independent equations. Whether i, E and M are endogenous or exogenous will depend on the specification of the monetary - and exchange rate regime. The classification of other variables will however be independent of such specifications:

Variables always exogenous: $i_*, K^S, K_*^S, P, Y, \pi_e$ and K_g .

Variables always endogenous: $W_p, W_g, W_*, K_p^*, K_{p*}^*, K_*^*, r$ and r_* .

Predetermined variables: $M_0, B_0, F_{p0}, K_{p0}, K_{p*0}, F_{g0}, K_{g0}, F_{*0}$ and K_{*0}

Let us substitute for W_p, W_g and W_* in equations (3.6) - (3.8) and then insert the expressions obtained into equations (3.10) and (3.11). By doing so, our model is reduced to 5 independent equations:

$$(3.4) \quad i = i_* + e_e(E)$$

$$(3.5) \quad \frac{M}{P} = m(i, Y)$$

$$(3.9) \quad r = i - \pi_e$$

$$(3.10)' \quad k \left(r, r_K, r_*, r_{K*}, \frac{B_0 + EF_{p0} + M_0}{P} + K_{p0} + \frac{EP_*}{P} K_{p*0} \right) + K_g = K^S$$

$$(3.11)' \quad \frac{M_0}{P} + K_{p0} + \frac{EP_*}{P} K_{p*0} - m(i, Y) - k \left(r, r_K, r_*, r_{K*}, \frac{B_0 + EF_{p0} + M_0}{P} + K_{p0} + \frac{EP_*}{P} K_{p*0} \right) + \kappa \left(r_*, r_{K*}, \frac{F_{*0}}{P_{*0}} + K_{*0} \right) = K_*^S$$

where, before specifying the monetary- and exchange rate regime, the endogenous variables are r and r_* .

3.2 Specifying the monetary - and exchange rate regimes

As we are primarily concerned with how the determination of the interest rate affects capital markets, let us introduce the following simplification: assume that we are dealing with a floating exchange rate regime. Thus, in addition to r and r_* , E will also be endogenous (and thus so will e_e). Whether there will exist a solution to our model will depend on the specification of the monetary regime.

Suppose first that both i and M are endogenous, hence the monetary authority leaves it up to the market to determine the price on money and simply serves as a supplier of liquidity in the economy. In this case we will have 5 independent equations to determine 5 endogenous variables: r, r_*, E, M and i . This indicates that a solution of our model will exist. Note that from equation (3.10)', we will get an expression for E as a function of r and r_* . Inserting for E in (3.4) and then for i in (3.5) will give us i and M as functions of r and r_* , respectively. Then, inserting for i in (3.9) will give us r as a function of r_* . Hence E, i, M and r will all be functions of r_* . Inserting in (3.11)' gives one equation in one endogenous variable, namely r_* . This gives us a solution of r_* , from which the solutions of the four remaining endogenous variables follow. We end up in a situation where the amount of real capital supplied equals the amount demanded. Hence the law of indifference will hold in the asset market. No one will have incentives transferring funds from financial markets to the market for real capital, in either country.

Next, suppose that i is the monetary policy instrument, hence it is exogenous. In this case we have 5 equations to determine 4 endogenous variables: r, r_*, E , and M . In this case E will be determined in equation (3.4), M in equation (3.5), and r in equation (3.9). Then we are left with two equations, that is (3.10)' and (3.11)' to determine one variable, r_* . Suppose it is determined by (3.11)', and thus that both domestic and foreign residents are willing to hold the amount of foreign real capital that ensures that the law of indifference holds in the foreign

market for assets. But then, only by coincidence will this real rate of interest give domestic investors incentives to hold the amount of real capital that will lead the law of indifference to hold for domestic real capital as well. In particular, one of the following three situations will occur:

$$(a) \quad k \left(r, r_K, r_*, r_{K*}, \frac{B_0 + EF_{p0} + M_0}{P} + K_{p0} + \frac{EP_*}{P} K_{p*0} \right) + K_g > K^S$$

$$(b) \quad k \left(r, r_K, r_*, r_{K*}, \frac{B_0 + EF_{p0} + M_0}{P} + K_{p0} + \frac{EP_*}{P} K_{p*0} \right) + K_g = K^S$$

$$(c) \quad k \left(r, r_K, r_*, r_{K*}, \frac{B_0 + EF_{p0} + M_0}{P} + K_{p0} + \frac{EP_*}{P} K_{p*0} \right) + K_g < K^S$$

In case (c), too little will be invested in domestic real capital. One reason why this may occur is because the rate of return on financial assets is high, relative to the return on domestic real capital. This case can be associated with large values of B, F_p and M (which is most likely to happen for high values of r). The low demand for real capital implies that its real rate of return will be low, weakening incentives to invest in real capital. This reduction in investment will not only result in a reduction in the stock of real capital (through depreciation), but will also infect economic activity in general and eventually lead to a reduction in overall inflation. Hence this situation can be characterized as the bust of a boom - and bust cycle. Case (a), on the contrary, may be characterized as a boom. In this case portfolio managers' demand for real capital will be so large that investment will be tremendous, and the price of real capital will increase. The increase in prices will give even stronger incentives to invest in real capital, and thus the original effect will be amplified. Case (b) will be the case in which, by coincidence, the same value of r_* clears both the domestic and foreign asset markets, implying that the law of indifference holds in both. However, just as for the closed economy, this relationship will not be stable.

4 Some remarks on the empirical relevance and “testability” of the theory

In the above chapters we have seen that certain logical problems may exist in portfolio models where real capital functions both as an asset and as means of earning profits (rents) from owning machines, buildings, and other productive equipment. The result we established was that the system became overdetermined in the mathematical sense if the short term interest rate was fixed exogenously by the central bank. Overdeterminedness can be translated to “not in equilibrium”- or “outside equilibrium” – situations, which we as economists associate with some degree of “chaos” with low predictability. We then have our paradox, namely that any attempt to use the interest rate as an instrument for controlling for example the nominal exchange rate, or inflation, or minimize business fluctuations, may lead to a loss of ability to forecast the macro economy.

In the rest of this thesis, some hypotheses from Haavelmo's theory about the (dis)equilibrium-constellations between asset markets and the real economy will be tested against data.

“Testing” will in our case involve empirical evaluation in a rather broad sense. First, since the pure version of the model is so abstract and stylized, one cannot come about a rather broad interpretation and introduce auxiliary assumptions in order to make it operate. For example, agents probably do not have a precise and uniform assessment of the marginal return on real capital (the derivative of the macro production function). Thus, even if the disequilibrium situations above have empirical relevance, their effects will not be as clear cut as what is implied by the pure theoretical model.

The model's message is that asset markets and the real economy cannot be analyzed in isolation: Instead of regarding the determination of the activity level of the real economy as separate from the asset and loans market, Haavelmo's point seems to be that the real economy is deeply conditioned by the nature of equilibria or disequilibria in these markets.

One hypothesis that emerges is that periods where the interest rate has been used as an instrument to achieve very tightly specified nominal targets, for example nominal exchange rate stability, may result in either a build-up to or even an outbreak of macroeconomic

imbalances. To test this implication systematically one would probably need to investigate long historical data series from many countries, but time constraints prevent me from following that approach here.

Rather, I will inspect important individual cases in more detail to see if the "mechanism" of for example the great depression between WW-1 and WW-2, or the current credit and job crises, can be postdated by Haavelmo's model. Although we will not go far in that direction, it is striking that when the recession started in the late 1920's it was made worse by the strictures of high interest rates that the authorities in many countries felt were necessary to retain scarce gold reserves and avoid devaluation. In USA in particular, late in 1931, when the downturn in real activity had become visible on both sides of the Atlantic, the Federal Reserve raised interest rates sharply to show the country's commitment to the gold standard, as we will come back to in chapter 5.

It is not very controversial to claim that the above policy was one of the factors that turned a downturn into the Great Depression, but it also fits well with the predictions of Haavelmo's model. When the downturn came, and an already high discount rate was further increased, the real rate of return on physical capital no longer matched the returns that investors demanded. In our simple model-economy, this would result in a movement from a situation with high investment in real capital (and resulting jobs and income generation) to one where it is negligible, or even worse, dries up completely. According to the model such a situation is made worse by reduced inflation, which is exactly what happened.

Finally, the model predicts that after the Depression became a reality, a lowering of the interest rate level that would have stimulated the economy early in the recession, would lose its force, and without external fiscal stimulus low activity in the economy would prevail for a long period of time. It is a widely held (but not universally agreed) view that low interest rates, made possible by massive market operations by the Federal Reserve (i.e. the central bank holding a large portion of government debt) together with the increase in real demand created by the war effort, fed the boom in stock prices. Once again, as predicted by Haavelmo's model.

The above suggest that Haavelmo's model is relevant for analyzing one of the really big events in modern economic history. Next we are interested in posing several hypotheses that can be tested econometrically on U.S. data since WWI. There are two reasons why this data

has been preferred to other. First, the U.S. economy has been without explicit regulations and controls during the period, so one premise for the relevance of the theory is in place. Second, the conduct of monetary policy has been subject to changes, providing us with data from different monetary policy regimes.

According to Haavelmo's model, targeting the interest rate may result in situations where changes in the real rate of return on real capital are not represented by changes in the interest rate and in that way may lead the economy into disequilibrium. Thus large fluctuations in important economic variables would be expected. The presence of large fluctuations can be investigated empirically in several ways. In this thesis, I rely mainly on two methods: Investigation of significant non-linear effects by estimation of non-linear functional forms, and detection of large outliers that signify sudden changes in for example housing prices that cannot be explained by the included explanatory variables.

However, before turning to the empirical part of the thesis, which waits in chapter 6, the monetary regimes have to be identified. A historical overview of U.S monetary policy follows in chapter 5.

5 Monetary policy in the U.S. since the foundation of the Federal Reserve System⁵

The Federal Reserve System (Fed for short), the central bank of the United States, was founded by Congress in 1913 primarily as a reaction to the many financial panics that the country had experienced in the past, particularly the severe crisis in 1907. The hope was that the Federal Reserve Banks, through extension of credit to commercial banks, could prevent bank runs or shortages of currency from evolving to financial panics and eventually a breakdown in the overall economy.

THE GOLD STANDARD

Gold was monetized by the Treasury through issuance of gold certificates to the Federal Reserve. This was a key element of the so called gold standard, which was in operation from 1900 -1971.⁶ The main mechanism of the system was that whenever money supply increased, bringing about increases in inflation, it was evident that large amounts of gold had found their way to the US. This implied that gold had become less scarce, and accordingly its return decreased. In response, gold flowed out of the country, the Treasury's money-making activity diminished, and the initial inflationary tendencies were reduced. However, how was it possible for the Federal Reserve System to serve its other purpose alongside the gold standard? For example, situations when credit provisions to domestic banks were required might very well occur at a point in time when the flow of gold into the country was modest.

FINANCING WAR EFFORT

After World War I (WWI) broke out in 1914, European countries demand large volumes of goods for the war effort. Many turned to the U.S. to purchase these goods and gold flowed

⁵ The presentation in this section is based on those presented by the Federal Reserve Bank of New York at <http://www.ny.frb.org/education/addpub/monpol/> , the Federal Reserve Education at <http://www.federalreserveeducation.org/about-the-fed/history/> and <http://www.federalreserveeducation.org/about-the-fed/history/2006andbeyond.cfm> , and the Federal Reserve Board's publication "The Federal Reserve System: Purposes and Functions", available at <http://www.federalreserve.gov/pf/pf.htm>

⁶ However, as will be evident from the forthcoming presentation, during this period the country was, at least once, taken off the gold standard until a new parity was established.

into the country. The inflationary pressure of these inflows was evident, but the Fed took no actions in order to dampen them. However, as the U.S. itself entered WWI in 1917 and extended large loans to its allies, the flow of gold into the country almost disappeared, reversing the initial inflationary pressure.

To finance the war effort, Treasury debt was issued on a large scale, and the Secretary of Treasury insisted that the Fed hold down interest rates while these issues were being sold. Initially these certificates of indebtedness were offered at rates substantially below market rates, presumably to ensure that the Federal Reserve ended up with the entire issue.⁷ This arrangement was met with criticism, and shortly after certificates were sold at competitive rates. Still, the Federal Reserve had to intervene: To provide member banks with incentives to buy Treasury securities, the Federal Reserve stated that Treasury securities would be highly rated collateral when borrowing from the discount window. Effectively, it risked ending up with these issues as well. There was no doubt that a large expansion of Federal Reserve credit had occurred, and it now took the place of gold inflows as the major source of growth in money and credit.

OPEN MARKET OPERATIONS AS A COUNTERCYCLICAL TOOL

Also after the war, the discount rate was held low to make credit easily accessible for the Treasury and led gold to flow out of the country. As the country was still on the gold standard such a development was not welcomed, and the Treasury dropped its opposition to higher rates in 1920. Gold outflows were reversed, but the increased interest rates contributed to a dramatic decline in money and prices, and a short but severe economic contraction.

In 1923 the Open Market Investment Committee (OMIC) was established, and during the recession one year later it began, with Treasury approval, to use open market operations as a countercyclical tool.⁸ By watching short term money market interest rates and the use of discount window lending, the OMIC decided on whether credit was tight or easy and made open market operations accordingly. This reminds a lot of the monetary regime today, but knowing that banks made heavy use of the discount window during the 1920s and that the

⁷ The advantages of Federal Reserve holdings of Treasury debt became evident in 1922. During this year the Treasury realized the inflationary pressure brought about by the large Federal Reserve Banks' holdings, and suggested they be liquidated, to which the Federal Reserve agreed. Had private investors held Treasury debt, such an agreement would have been hard to reach.

⁸ Earlier most Federal Reserve officials viewed open market operations as a source of revenue rather than as a tool for implementing monetary policy.

country was on the gold standard, the differences are evident. In particular, it is reasonable to assume that open market purchases would lead to increased economic activity only if they were not offset by gold outflows.

THE GREAT DEPRESSION

Initially, the Fed used moral persuasion to discourage banks from borrowing funds from the discount window to invest in financial instruments and feed the speculative boom in stock prices. This had only limited success, and eventually it agreed to raise the discount rate in August 1929, after New York Fed Governor Harrison's first suggestion in 1928 of a short-lived but sharp increase (tempered by increases in open market purchases) had been rejected by the Board of Governors. This rejection reflects well one of the major challenges facing the Fed during the 1920s: There was no consensus on the conduct of monetary policy. Some gave their support to a procyclical policy based on the demand for credit for commercial transactions (real bills), while others supported the countercyclical alternative: make credit easily accessible when the economy was in recession and put limits on it when the economy was growing rapidly.⁹

However, the increased discount rate came too late and included only limited use of open market purchases to soften the pressure of high rates. The stock market crashed on October 1929 and on that very day the New York Fed bought five times the amount of Treasury securities ordinarily authorized by the OMIC for a week. Unfortunately, this measure was not enough, and the country encountered the worst economic downturn in history, later referred to as the Great Depression (1929-1933).

The U.S. stock market crash was extremely bad news for the German economy, as it was practically built on loans from U.S. banks. As these loans came due, many German firms ended up in financial distress, and had no other choice than to liquidate their assets. Since Germany was the work horse of the European economy, the failure of German firms had effects across the entire continent, which experienced a great depression of its own.

⁹ The real bills doctrine is a theory of money creation that argues that issuing money in exchange for short term private credit is not inflationary. Accordingly, credit contractions only reflect that people no longer find any investment projects worth investing in, and thus creation of money will only lead to excess supply, and hence not be warranted.

Back in the U.S. there was a severe contraction in credit, but in accordance with the real bills doctrine the Open Market Policy Conference (OMPC) was initially reluctant to use open market purchases to stimulate economic activity.¹⁰ However, the Fed lowered the discount rate in several steps, but at a pace that lagged behind the effects of the contraction in money, credit and prices.

As Great Britain went off the gold standard massive gold outflows from the U.S. occurred, and in response the Fed decided to raise the discount rate. Specifically, the New York Fed raised its basic discount rate from 1 ½ to 3 ½ percentage points, an action that further strained an already weakened financial system. As discussed in chapter 4, this is exactly what Haavelmo's model would predict to happen on asset markets in this case.

In 1932 the OMPC gave in to pressure from Congress and the Hoover administration and bought a substantial amount of Treasury securities, which seemed to put the economy on the path to recovery. However, as the recent banking crisis had drained banks for currency, some of the extra money in circulation was used to increase excess reserves. The OMPC believed that this rise was due to shortages on lending opportunities for banks, and responded by making no more open market purchases after 1932.

RESERVE REQUIREMENTS AND PEGGED INTEREST RATES

In reaction to the Great Depression two important measures were taken. First, the Roosevelt administration took the country off the gold standard in April 1933, by which it allowed the price to rise in the market until it established a new parity of \$35 an ounce in January 1934, up from \$20.67. As a result gold flowed to the U.S., and was monetized by the Treasury via issuance of gold certificates to the Federal Reserve. Second, Congress passed two acts, the Banking Act (also known as the Glass-Steagall Act) of 1933 and the Banking Act of 1935.¹¹ With these acts deposit insurance was introduced, and people again trusted banks with their funds.

From these changes followed a rapid growth in money and reserves. In particular, banks built up large holdings of excess reserves, of which the inflationary tendencies were evident. The

¹⁰ The OMPC replaced the OMIC in 1930 and included transference of power from the Federal Reserve Bank of New York to the Board of Governors.

¹¹ Through the Banking Act of 1935 the OMPC was replaced by the Federal Open Market Committee (FOMC), which was given the sole right to buy and sell government debt, and was no longer a decision that each Federal Reserve Bank could make on its own.

Federal Reserve responded by increasing reserve requirement ratios dramatically, but banks continued their buildups of excess reserves, and contracted the money stock in the process. Economic activity contracted until 1938, at which point the Federal Reserve reduced reserve requirements.

To help Treasury finance war effort during World War II the Fed pegged, in April 1942, the rate at which it would buy Treasury bills at $3/8$ of 1 percentage point, a level that lasted until 1947.¹² This rate was lower than the discount rate, and thus banks that held Treasury bills found it more profitable to sell these to the Federal Reserve Banks than to use the discount window to borrow when funds were needed. As a result discount window borrowing became less important, and there was a large expansion in Federal Reserve credit.

Before we continue with our presentation let us have a closer look at figure 5.1. It plots the federal funds effective rate and CPI inflation (both explained in appendix A). Since stable inflation is (and has been) one of the primary goals of the Fed and the federal funds rate the variable it either targets or uses as an instrument to achieve this goal, such a figure is interesting to consider. In particular, it will be useful to combine with the presentation in the rest of the chapter, as it “illustrates” what is to be verbally concluded.

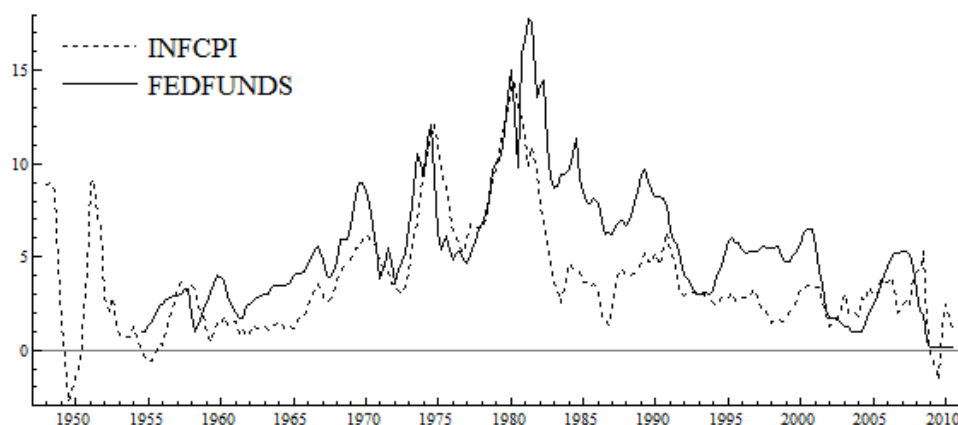


Figure 5.1: Plot of the federal funds effective rate and CPI inflation.

¹² At which point the Treasury agreed to an upward adjustment of rates on shorter maturities in order to decrease inflationary pressure.

FREE RESERVES TARGETED

In March 1951, the Federal Reserve was allowed to resume an active and independent monetary policy. Between 1953 and 1960, it pursued what came to be known as a “bills only” policy, generally confining open market operations to short-maturity Treasury securities.¹³

The FOMC was aware of the importance of interest rates in the economy, but did not want to establish interest rate targets in order to break with the strict pegging that occurred in the 1940s. Specifically, during the 1950s and 1960s special emphasis was given to the behavior of bank credit (commercial banks’ loans and investments) as an intermediate policy guide. The Federal Reserve wanted to speed up (slow down) credit growth whenever economic activity showed weakness (strength). As bank credit behavior is nearly impossible to watch in the short run, it was not a suitable goal for the Federal Reserve’s day-to-day operations. The choice instead fell on free reserves, defined as excess reserves less reserves borrowed from the discount window. Open market sales (purchases) were made when forecasts suggested that free reserves were significantly above (below) their objective.

During the mid-1960s banks started to borrow funds in the market, and thus the demand for federal funds increased. As a result the federal funds rate rose above the discount rate briefly in October 1964 and more persistently in 1965. Now banks could extend credit even when they did not have free reserves by borrowing funds from other banks. As a result free reserves’ ability to predict bank credit growth was reduced. Still it remained the primary target for implementing monetary policy throughout the decade.

CONTROLLING MONETARY AGGREGATES: 1971-1982

In the latter half of the 1960s rising inflation was recognized as a problem, and connections of free reserves and bank credit to the ultimate goals of economic expansion and price stability came to be questioned. The stage was set for a change in the conduct of monetary policy, and in the two decades to come emphasis was put on control of monetary aggregates. However, the way in which this control was performed differed from one decade to the next.

¹³ The “bills only” restrictions were abandoned by the FOMC in 1961 as interventions in markets for longer term maturities seemed necessary to stabilize economic activity.

FEDERAL FUNDS RATE TARGETED

In August 1971 the Nixon administration suspended gold payments and in that manner effectively ended the Bretton Woods exchange rate system, making industrialized countries move to floating exchange rate regimes.¹⁴ Now the Federal Reserve could tailor monetary policy to domestic economic activity, as it did not have to worry about fluctuations in the exchange rate.

During most of the 1970s, the FOMC selected objectives for growth of M1 over short time intervals, and targeted the funds rate accordingly. Hence the federal funds rate, as an indicator of money market conditions, became the primary guide for day-to-day open market operations, and free reserves took on a secondary role. The, earlier mentioned, increasingly active market for federal funds made the funds rate a feasible target, and bank credit received decreasing attention. Interest rates banks both paid and charged customers were affected by the federal funds rate, and thus so was the demand for money. If monetary aggregates were below (above) target growth rate during the intermeeting period the federal funds rate would be lowered (raised).

The FOMC was reluctant to change the funds rate by large amounts at any one time, even when this seemed to be necessary to achieve monetary goals.¹⁵ This was reflected by the development of the width of the intermeeting funds rate range. In the early 1970s, it was generally $5/8$ of a percentage point to $1\frac{1}{2}$ percentage points. By the latter part of the decade, the width had narrowed to about $1/2$ to $3/4$ of a percentage point.

NONBORROWED RESERVES TARGETED

Between 1970 and 1979 CPI inflation almost doubled, see figure 5.1, and inspired a change in the Federal Reserve's priorities. In late 1979, through Chairman Volcker's leadership, the quantity of reserves was targeted in order to achieve greater control of M1 and bring down inflation.¹⁶ Because required reserves were predetermined, the operational objective for open

¹⁴ The Bretton Woods system, enacted in 1947, created a system of fixed exchange rates that allowed governments to sell their gold to the United States at the price of \$35/ounce.

¹⁵ However, during the two oil price shocks in 1973 and 1979, respectively, the Fed reduced its target for the funds rate substantially in order to boost inflation, which is also apparent from figure 5.1.

¹⁶ Reserves refer to the sum of balances at the Federal Reserve and cash in the vaults of depository institutions that they use to meet reserve requirements.

market operations came to be a specific level of nonborrowed reserves, defined as total reserves less the quantity of discount window borrowing.

The FOMC made sure, at any time, to provide just enough reserves to meet the nonborrowed reserves objective. Thus whenever inflationary (deflationary) tendencies occurred, reflected by money growth above (below) its objective, banks would have to increase (decrease) their borrowing in response to the excessive (deficient) demand for total reserves. As discount window borrowing was discouraged, the change in aggregate borrowing would affect the federal funds rate. A band of 4 to 5 percentage points wide was allowed for the federal funds rate, which was far beyond the width allowed when the federal funds rate was targeted.

BORROWED RESERVES TARGETED

By late 1982 the link between M1 and economic activity had been weakened, and M1-targeting was suspended. In the day-to-day implementation of open market operations this change was reflected in the shift of focus from a nonborrowed-reserve target to a borrowed-reserve (funds borrowed from Federal Reserve Banks in order to maintain the reserve requirement) target. This targeting procedure (introduced in 1983) persisted, with modifications, through most of the 1980s and carried with it much smaller degree of variation in the federal funds rate than the policy of targeting nonborrowed reserves.

The Fed made sure to supply fewer nonborrowed reserves than the estimated demand for total reserves, forcing depository institutions to borrow at the discount window in order to meet their remaining needs for reserves. The level of the federal funds rate was influenced by changing the shortfall of supply and thereby also affecting the extent to which depository institutions had to borrow at the discount window. When the Federal Reserve wanted to ease monetary policy, it would reduce the borrowed reserves target and supply more nonborrowed reserves to meet estimated demand. Then the pressure to borrow at the discount window would be weakened, and the need to borrow in the federal funds market decreased. In response, depository institutions would bid less aggressively for balances at the Fed, and the federal funds rate would fall.

BACK TO TARGETING THE FEDERAL FUNDS RATE: 1983

Beginning in the mid- 1980s some depository institutions were struggling financially, and relied on discount window borrowing to manage their day-to-day operations. In such circumstances any amount borrowed from the discount window could be taken as a signal of financial weakness, and eventually lead to a run of depositors. Consequently, depository institutions were reluctant to borrow at the discount window. As a result the link between borrowed reserves and the federal funds rate was weakened: a high level of the federal funds rate could just as well be accompanied by low, as high, borrowed reserves. The Federal Reserve had to give up control over one of these variables in order to control the other, and moved in the direction of interest rate targeting.

In October 1987, two months after Alan Greenspan took office as the Federal Reserve's Chairman, the stock markets crashed, and in response interest rates were lowered rapidly, see figure 5.1. Throughout the 1990s the Federal Reserve more actively and openly geared monetary policy towards targeting real economic activity and inflation control. This may have been one of the reasons why this decade was marked by generally declining inflation (see figure 5.1) and the longest peacetime economic expansion in U.S. history. Also, by starting to announce its target for the federal funds rate in July, 1995, the FOMC made monetary policy more transparent, which probably had its contribution to the economic expansion.

The terrorist attacks on September 11, 2001, disrupted U.S. financial markets, to which the Federal Reserve responded by lowering interest rates and taking on the role of a lender of last resort for financial institutions. In 2003 discount window operations were changed as the discount rate was set above the federal funds rate, and rationing of loans to banks through interest rates was provided. The consequences of such actions are many and different, one of them being that depository institutions chose to borrow funds in the federal funds market rather than at the discount window. To what extent did they contribute to the forthcoming financial crisis? Answering this question will not be the objective of this thesis, but I could not help raising it.

SLASHED FEDERAL FUNDS RATE TARGET

As a result of the interest rate cuts during the early 2000s in order to help US financial institutions in distress, mortgage rates were low and the access to credit expanding. Hence

homeownership was made possible for more people, increasing the demand for houses and thus driving up house prices. There was clear evidence of a boom in the housing market, but, as history suggests, booms are followed by busts. Accordingly, during 2006, housing prices started to fall, which for some homeowners meant that their house was worth less than what they owed at their mortgages. Thus they were given incentives to default on their loans, and the number of delinquent mortgages (at least one payment past due) and mortgages in foreclosure started increasing, and eventually exploded.

As mortgages had been securitized and traded on financial markets, the defaults on U.S. mortgages had effects far outside U.S. borders and led losses to spread across the globe. This situation reached a crisis point in 2007 when fears about the financial health of financial institutions led banks to contract credit provided to this group. As a result the rates on short-term loans rose sharply relative to the overnight federal funds rate. Confidence in the financial sector collapsed and stock prices of financial institutions around the world plummeted. For banks this meant that loans were hard to sell, and therefore they tightened standards and demanded higher interest rates from potential borrowers. A classical credit crunch was realized. The Fed used all tools available in order to give a boost to economic activity. However, federal funds rate targeting was never abandoned, but the rate was brought down to nearly 0 by December 2008, the lowest level in 50 years.

A GRAND SUMMARY

The timeline presented in figure 5.2 gives a summary of the above presentation, from which the following pattern appears: Since the foundation of the Fed control of interest rates, sometimes more apparent than other, has been used as an instrument for the varying targets of monetary policy. In some periods, a low interest rate has been a target in itself. This is interesting because it makes it relevant to use US data to see whether there are any signs of very high investment activity, maybe together with sharp (and unsustainable) hikes in housing prices, after a prolonged period when the return on financial assets can be judged to have been low compared to the return on real capital. Hence, in accordance with our theoretical model, we would expect the occurrence of booms and busts in investment activity during this period to be partly explained by fluctuations, or lack of those, in interest rates. In chapter 6 this hypothesis is tested by considering the effect of the federal funds effective rate (FEDFUNDS) on the investment rate and housing prices, a choice of variables that will be explained therein.

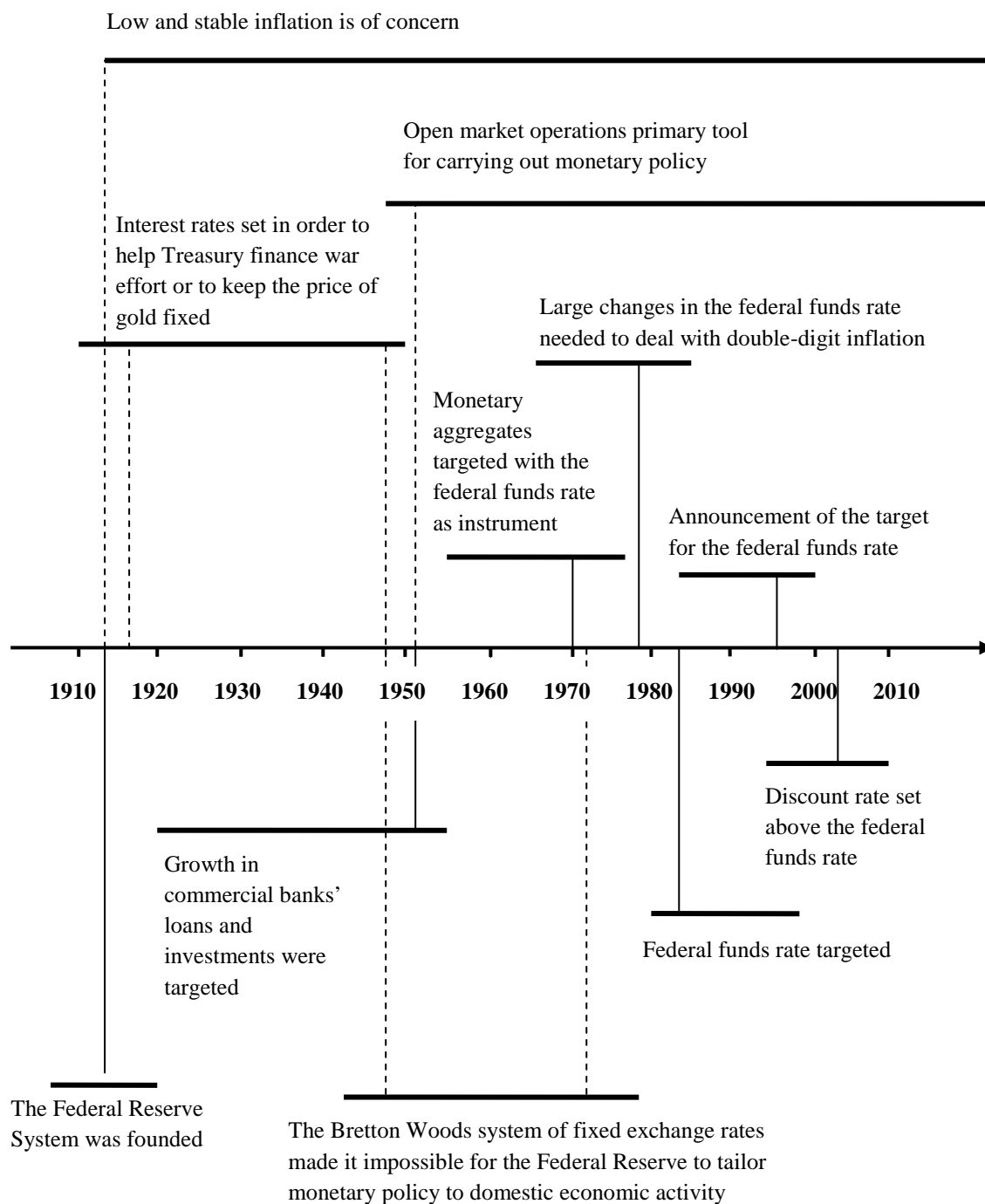


Figure 5.2: Timeline of monetary policy targets

6 Descriptive statistics and econometrics tests

The purpose of this chapter is to test whether there is something to the theoretical implications, namely that monetary policy implementation through interest rate control may lead to large and persistent fluctuations in investment and eventually in other important macroeconomic variables. The choice of variables is guided by theory, and represents variables that (in light of chap. 5) either have been targeted by the Federal Reserve or, more importantly, have been influenced by policy decisions. In the formal model in chapter 2, the assumption is that a profitability consideration related to the marginal return and productivity of real capital plays a significant role in the determination of the aggregate activity level, and our focus will be on this. Hence it is in line with theory to analyze business investments, which we do in section 6.4. However, in the U.S. case it seems relevant to consider the market for residential housing as well, for which the reason is given in section 6.3. First, an explanation of how the forthcoming econometric models have been selected is appropriate.

6.1 Automatic model selection

In the econometric modeling I have made use of *Autometrics*, which is a computer program for model selection that features in PcGive version 13. *Autometrics* makes general-to-specific-modeling (GETS) less time consuming (not to say manageable) than what would have been the case if it was to be performed manually. The general idea of GETS- modeling is straight forward, the operational details of a computer algorithm is another matter, and *Autometrics* may seem like a “black box”. While a detailed exposition would take too much space, I have found it useful to include a brief exposition of what I see as the main characteristics of *Autometrics*. I stress that this is my interpretation and not a blue print of the technical documentation, see Doornik and Hendry (2009).

Suppose that we are interested in modeling a variable y . First step is to specify an initial general model (in our case very simple) in which all the variables that are relevant in light of economic theory (or theories), and our knowledge of the subject in matter, are included. This model is called the general unrestricted model (GUM), and will in our example be:

$$(6.1) \quad y_t = \beta_0 + \beta_1 x_t + \beta_2 x_{t-1} + \beta_3 x_{t-2} + \beta_4 x_{t-3} + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-3} + u_t$$

It is desirable that both the GUM and the more specific models obtained through the later deletion of variables have satisfactory misspecification tests (SMT). However, *Autometrics* will start a simplification process even if there are some signs of misspecification. The logic is that the GUM represents “the best we can do” in terms of input, so we can go on to model y .

The estimation results of a GUM may have either of the following characteristics, of which the latter is more likely. First, all the explanatory variables may prove to be individually statistically significant, in which case no deletion of variables is possible, and the GUM is itself the final model. Second, one or several explanatory variables might be individually (or collectively) statistically insignificant, and *Autometrics* will start its search for a simpler model.

Suppose that in our case that estimation of equation (6.1) shows that both x_{t-3} and y_{t-3} are individually statistically insignificant. Hence deletion of variables is appropriate, and the search for a more specific model can begin. An example of how *Autometrics* might perform such a search is illustrated in figure 6.1. The first step includes deletion of either of the two variables, or both. As indicated in figure 6.1, deletion of both will result in a model that does not have SMT, and *Autometrics* might choose not to count it as a terminal model. Separate deletion of either variable however results in two distinct terminal models with SMT. Now, how will the final model be chosen, knowing that *Autometrics* will end up with a unique final model? First *Autometrics* starts out by creating a union model of the terminal models, and thereafter there are three different possibilities. First, GETS performed on the union model itself may result in no more terminal models than those unionized to create it, in which case either of them with the lowest Schwarz criterion will be chosen. Second, it may result in one new terminal model, which will be the final model. Third, it may result in several new terminal models, from which a union model will be created, and the three different possibilities just described will be present also in this case. Eventually, one final model will be selected.

Even though *Autometrics* is an automatic model selection, it gives the modeler the opportunity to choose the level of significance, which is the probability of including an irrelevant variable in the final model. For example, choosing a level of significance of α % implies that one might risk that α % of those variables included in the final model actually fail to explain any variation in the dependent variable. Traditionally, GETS has been criticized for having a larger probability than the chosen $1 - \alpha$ of failing to include a relevant variable in the

final model. However, this criticism does not seem to apply for *Autometrics*, see Ericsson (2010).

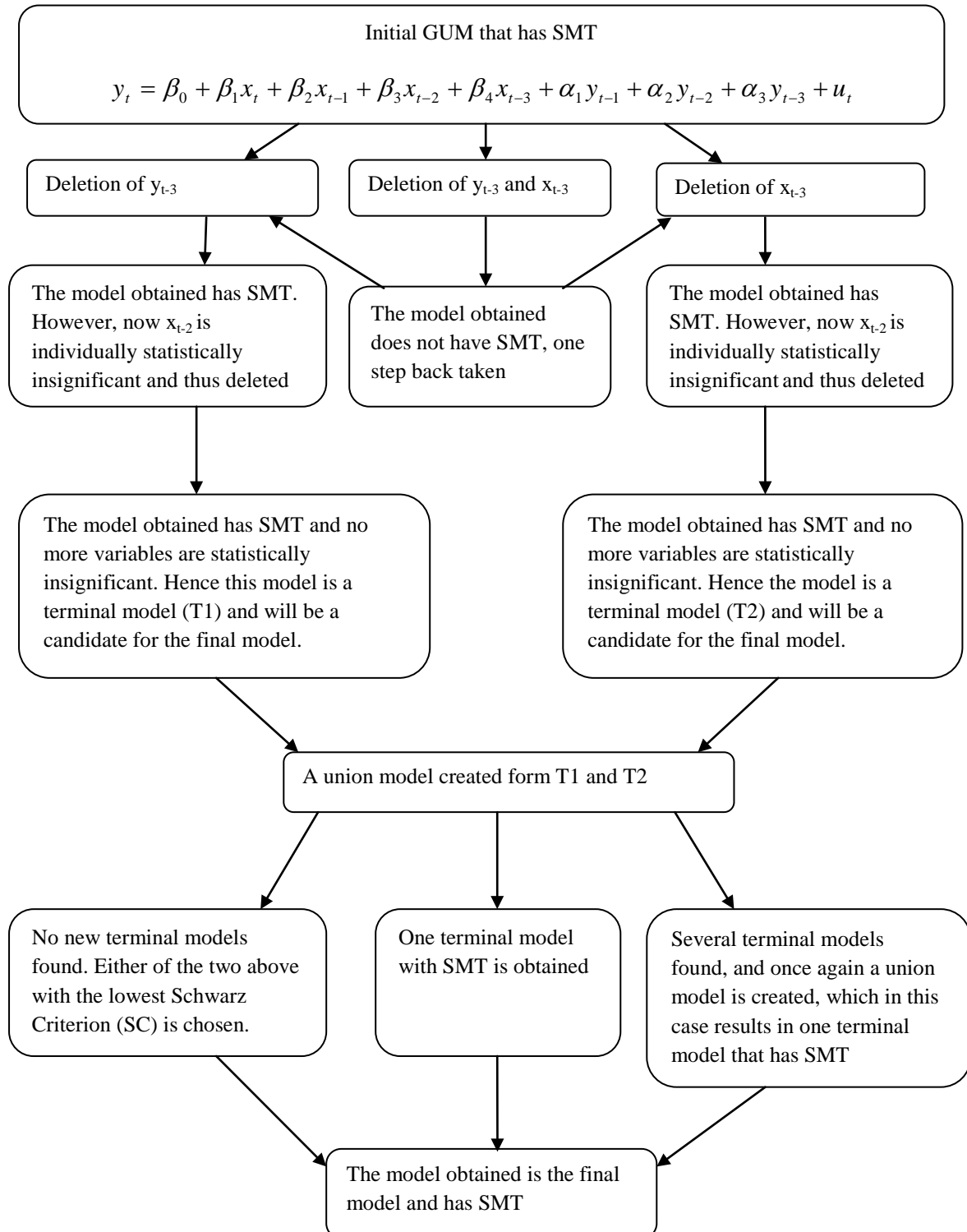


Figure 6.1: An example of how *Autometrics* works.

The significance level puts the premise for the model reduction, which will not always lead to a unique terminal model. In some cases, *Autometrics* might end up with several terminal models even after applying the union model, as illustrated in figure 6.1. The final model will then be either of the terminal models with the lowest Schwarz Criterion (SC). Following Doornik and Hendry (2009), let T be the number of observations and k the number of regressors, then SC is given by:

$$(6.1) \quad \log \tilde{\sigma}^2 + k \frac{\log T}{T},$$

where $\tilde{\sigma}^2$ is the maximum likelihood estimate of σ^2 :

$$(6.2) \quad \tilde{\sigma}^2 = \frac{T-k}{T} \hat{\sigma}^2 = \frac{1}{T} \sum_{t=1}^T \hat{u}_t^2, \text{ with } \hat{\sigma}^2 = \frac{1}{T-k} \sum_{t=1}^T \hat{u}_t^2$$

As I hope has been evident from the above presentation, there is no doubt that *Autometrics* helps save time in general to specific modeling. However, its usefulness does not stop here. It can also be instructed to detect outliers in the final model, which can be done in two distinct ways. First, impulse dummies for each observation can be included in the GUM before searching for a simpler model, a process known as indicator saturation (IS). Second, impulse dummies can be included in the final model for those periods in which the residuals are so large that the randomness of errors is questioned. Notice that one of the differences between the two detection methods of outliers just described is the null hypothesis: in the first the null hypothesis is that they are present, whereas in the latter it is the opposite, namely that outliers are not present.

6.2 Trends and breaks in the US federal funds effective rate

As a background, I first investigate whether there are signs of and evidence for structural breaks in the federal funds effective rate (FEDFUNDS). If the federal funds rate has been a policy target in some periods, and an instrument in others, the periods where the changes occur ought to show up as structural breaks (which can be modeled by dummies) in a simple time series model of the FEDFUNDS. Moreover, in the periods where the interest rate is an instrument, any changes in policy priorities (e.g., price stabilization versus. financial stability

or exchange rate stabilization), may also show up in the econometric model. The relevance of this is twofold: First, it is of interest to see if the monetary policy interpretation in chapter 5 can be confirmed by the break points found in an econometric model. Second, if there are significant breaks in the equation, these may represent periods where we also expect sharp changes in macro variables such as housing prices and investments, which both will be considered in later sections of this chapter.

To check for such structural changes we start out with a GUM with FEDFUNDS as the dependent variable, and its 5 lags as regressors. Since no explanatory variables have been included, I instruct *Autometrics* to include an impulse dummy for each and every observation (IS), of which only some (as will be apparent in the following) will survive the automatic process of deletion of variables. Further, I have instructed *Autometrics* to keep the intercept in the final model, which is important for the interpretation of the steady-state as an estimate of the long-run equilibrium FEDFUNDS. Since this variable is likely to affect also the variables considered later, I set the significance level to 1%, in order to have a low probability for inclusion of irrelevant variables in the final model. Otherwise, a significance level of 5% will be chosen.

Several of the impulse dummies are included in the final model, and in order to simplify matters I introduce a new variable, FEDFUNDSbreak, which will be equal to the estimated coefficients in the periods for which impulse dummies are included in the final equation, and 0 otherwise. This variable gives the percentage change in the interest rate as a result of structural changes, one example being changes in the conduct of monetary policy. The estimation results are reported in table 6.1. A lagged variable is denoted by (t-1) after the variable name. This notation will also apply for all other tables that appear in the remainder of this thesis. Continuing what is already started, a twice lagged variable is denoted by (t-2) after the variable name, (t-3) behind a variable name denotes its third lag, and so forth.

Table 6.1: Structural breaks in the federal funds effective rate, FEDFUNDS

Endogenous variable: FEDFUNDS		
Regressor	Coefficient	t-value
FEDFUNDS(t-1)	1.5556***	66.4
FEDFUNDS(t-2)	-0.7264***	-20.5
FEDFUNDS(t-3)	0.1381***	6.15
Constant	0.1758***	4.39
FEDFUNDSbreak	1.0000***	41.7
Diagnostic tests		
AR 1-5 test	F(5,208) = 2.0030	
ARCH 1-4 test	F(4,210) = 0.40044	
Normality test	Chi ² (2) = 3.6641	
Hetero test	F(8,209) = 1.6326	
Hetero X-test	F(14,203) = 1.0221	
RESET 23 test	F(2,211) = 0.65630	
Other		
No. of observations	218, [1955(4)-2010(2)]	
R ²	0.992376	
$\hat{\sigma}$	0.295298	

*p<0.05,**p<0.01,***p<0.001

The results presented in table 6.1 show that three of the five lags in the interest rate are kept in the final model and that the FEDFUNDSbreak is highly significant (as can be seen from the rather high t-value). Below the coefficient estimates, I report several diagnostic tests for the final model. Appendix B gives an explanation of the different tests, but briefly: AR 1-5 tests for residual autocorrelation of order 1-5, ARCH 1-4 tests for autoregressive residual heteroscedasticity of order 1-4, Normality tests for not normally distributed residuals, Hetero and Hetero –X both test for residual heteroscedasticity, and the RESET23 tests for omitted variables and incorrect functional forms. The last lines of the table give the number of observations (and the sample period), together with the multiple correlation coefficient and the estimated residual standard error, $\hat{\sigma}$.

In table 6.1, and all other tables with estimation results, superscripts with *, **, and *** appear. These are related to the probability value of the relevant test, of which a short explanation follows. Apart from the normality test, almost (the normality test excepted) all the test statistics reported are valid for tests in which a null of all zero coefficients is tested against the alternative that at least one is non-zero. Following Kennedy (2008), the p-value of a test will then give us the probability, under the null hypothesis, of the test statistic taking on a value that is in absolute value larger than the one observed. In other words, it will give us the probability of rejecting the null hypothesis when it is indeed true, committing a type I

error that is. Knowing that the chosen significance level of a test gives us the level at which the modeler accepts committing a type I error the relation to the p-value seems apparent: Whenever the p-value is smaller than the significance level, the null will be rejected.

We note that the sum of the coefficients of the lags is less than 1. Hence, according to the estimation, there exists a stable long-run solution of the FEDFUNDS, which we can interpret as the long-run mean of the federal funds effective rate.¹⁷ Making use of the results in table 6.1, and the assumption that the expected value of the variable FEDFUNDSbreak will be 0 in the long-run, the long-run mean FEDFUNDS is calculated to be:

$$\text{Estimated long - run mean FEDFUNDS} = \frac{0.1758}{1 - (1.5556 - 0.7264 + 0.1381)} \approx 5.3761$$

In figure 6.2 we have included this variable along with the FEEDFUNDS and all the impulse dummies of which FEDFUNDSbreak is composed. It is interesting to see how the FEDFUNDS fluctuates along its estimated long-run level. Notice especially that during the 10-year period from 1990 to 2000 the FEDFUNDS level does not deviate as much from its estimated long-run mean level as during other periods of the same length, which is interesting as this period was marked by the longest peacetime expansion in the U.S. economy ever seen.

Further, it would be interesting to see how the structural breaks in the FEDFUNDS relate to the conduct of monetary policy. With the presentation in chapter 5 in mind, recall that in the beginning of the 70s the US ended the Bretton Woods system of fixed exchange rates and went on to target monetary aggregates with the federal funds rate as instrument. This change may have been followed by some of the breaks during the 70's. However, some of the breaks almost surely are reflections of the increases in the price of oil (1973 and 1979), and the different measures taken by the government to tackle the oil price shocks.

Note in particular, the numerically significant structural breaks in the early 1980s, which can certainly be matched to changes in the conduct of monetary policy. In 1979 Volcker became chairman of the Board of Governors of the Federal Reserve System and responded to the two-digit inflation by sharp increases in the federal funds rate target, which was a huge change compared to the previous policy of targeting interest rates.

¹⁷ In principle, a 95% confidence interval for the sum of the autoregressive parameters could be found to include 1; in that case the interest rate would be a so called unit root series. A formal test of unit roots is not considered here.

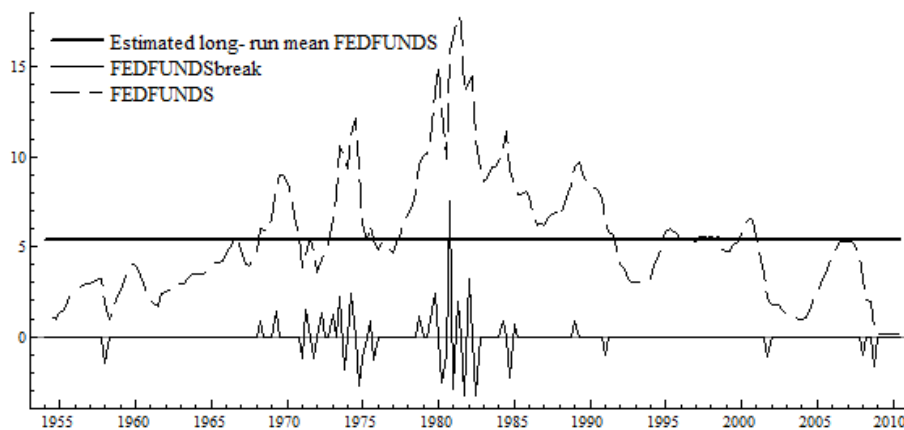


Figure 6.2: The FEDFUNDS, its long - run mean and structural breaks.

Also, the effect of the recent financial crisis seems to have led to a structural break in the series, as the Fed attempted to boost economic activity by large reductions in the federal fund rate target, approaching the lower bound of 0.

6.3 Housing prices and the interest rate

The theoretical model presented in chapter 2 was probably invented to help understand the often large –and long-lasting fluctuations in private nonresidential fixed investment, i.e. investments in production factors. Such an analysis waits in section 6.4. First, as discussed in chapter 4, the model seems relevant for the understanding of the mechanism of the Great Depression, and then it would be interesting to see whether it can also explain the financial crisis of 2007. The consensus view is that this crisis was initiated by the burst of a housing bubble, and I therefore start with an analysis of housing prices.

Two features seem to distinguish the US housing market from the European. First, the market for residential housing has been deregulated for the length of our sample period, satisfying the assumption in the initial model by Haavelmo. Second, investments in residential housing seem to be driven by the desire to make money as private households and construction companies are primarily concerned with the expected cash flow residential housing generates. In particular, the larger the expected cash flow compared to the interest paid on mortgages, the more profitable residential investment gets. Hence we may hypothesize that from low FEDFUNDS follow cheap mortgages, making residential housing affordable for more people. This may result in such an aggressive bidding for residential housing that housing prices rise so sharply that a bubble is created. However, this is only one side of the story. Housing prices

may also be positively affected by increases in the FEDFUNDS. If there is a speculative behavior in the housing market, an increased interest rate may lead to expectations of a rise in housing prices so large that it will outpace the increase in borrowing costs, once again, creating a bubble. These relationships between the FEDFUNDS and housing prices will be of primary concern herein, even though the mechanisms operating in the housing market are far more complicated.

The variable considered will be the national housing price index (HPI), which I have constructed for the purpose of this thesis, as explained in Appendix A. What is of particular interest in our case is to see to what extent changes in the FEDFUNDS affect the cyclical component of a time series, in this specific case that of the house price index (HPI). Notice that we are considering fluctuations in the log of nominal housing prices, LHPI, which is convenient as it can be approximated to percentage changes in housing prices.

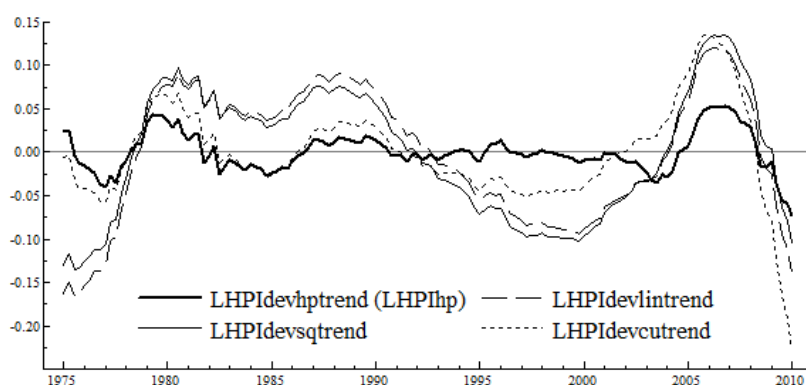


Figure 6.3: Four alternative time series of LHPI as deviation from trend.

However, it is important to notice that the cyclical component will strongly depend on how the trend component is measured, as illustrated in figure 6.3. In this thesis I will make use of four different trends. Three of them are deterministic; the linear, the square and the cubic trend. The fourth trend calculation is a time varying trend and is constructed by use of the Hodrick Prescott (hp) filter.¹⁸

As has already been stated in the introduction, we do expect the FEDFUNDS to affect housing prices, and a convenient starting point is to have a closer look at the cross correlation function between the log of housing prices, LHPI, and the FEDFUNDS. In general, this function graphs the correlation coefficients between a series x_t and the lags of another series

¹⁸ Confer Appendix B for an explanation of these trends.

y_t . Let \hat{c}_i^{xy} denote the sample cross-covariance, and \hat{c}_0^x and \hat{c}_0^y the variances of the x series and the y series, respectively. Following Doornik (2009), the cross correlation function is then

$$\hat{r}_i^{xy} = \frac{\sum_{t=i+1}^T (x_t - \bar{x})(y_{t-i} - \bar{y})}{\sum_{t=1}^T (x_t - \bar{x}) \sum_{t=1}^T (y_t - \bar{y})} = \frac{\hat{c}_i^{xy}}{\sqrt{\hat{c}_0^x \hat{c}_0^y}}, \quad i = 0, 1, 2, \dots, T-1,$$

using the full sample means \bar{x} and \bar{y} .

In our case the x-variable will be LHPI and the y-variable the FEDFUNDS. The results are reported in figure 6.4. All 20 cross correlation coefficients seem to be significant, as they are all outside the “corridor” indicated by the two thicker lines in figure 6.2. Hence changes in the FEDFUNDS seem to have an effect on housing prices, although diminishing. Further, it appears as if the FEDFUNDS leads housing prices.

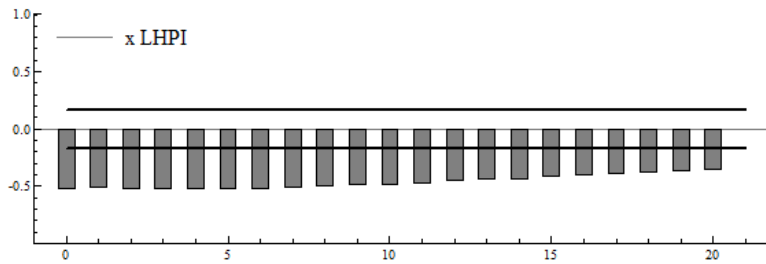


Figure 6.4: Cross correlation function between FEDFUNDS and LHPI.

However, we would expect the effect of the FEDFUNDS on housing prices to depend on the initial level of the FEDFUNDS, which is confirmed by figure 6.5. It is a scatter plot measuring LHPI along the vertical axis and the FEDFUNDS along the horizontal. 10 regression lines are included, each with the same number of observations included, and are all results of a regression of LHPI on the FEDFUNDS by use of ordinary least squares (OLS). The constant shift of the trend lines to the right reflects the existence of a trend component of housing prices.

The following pattern appears: If the FEDFUNDS is initially low, a marginal rise will result in significant reductions in housing prices. However, for higher initial FEDFUNDS, the effect of it increasing becomes less significant, and in a couple of cases it even changes sign. In particular, for high initial levels of the FEDFUNDS, there seems to be negligible effects on housing prices of changes in the FEDFUNDS.

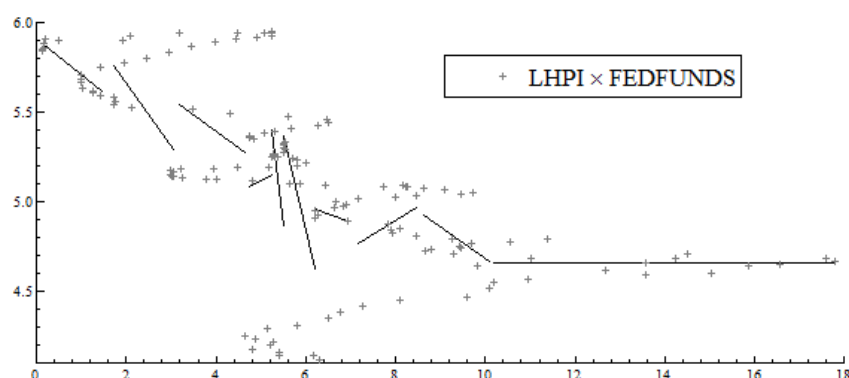


Figure 6.5: Scatter plot of FEDFUNDS and LHPI with 10 sequential regression lines.

We will primarily be interested in the effect of interest rate control (by the Fed) on housing prices and will thus focus on the nominal federal funds effective rate. However, let there be no doubt about the fact that investors will make decisions based on the real interest rate (as seen in the core model presented in chapter 2), but since rules such as the Taylor rule ensure that there is no contrast in the movement of the real and the nominal interest rate, I believe that the validity of the empirical results will not be endangered.

Further, there are two more reasons why the nominal interest rate rather than the real interest rate has been included, both related to the measurement of the latter. First, the real interest rate depends on inflation expectations, of which observations are impossible and approximations beyond the scope of this thesis. Second, given that it was observable, expectations of what inflation should be included? The convention is to use consumer price inflation but this is very crude both theoretically and practically, as the relevant price increase may be specific to sector products, for example. In principle one should also account for capital depreciation and for tax rates when calculating the user cost of capital.

These issues are important but would take us beyond the scope of this thesis. Instead we have modeled the empirical relationship between the nominal interest rates and investment and housing prices “heads on”. It is understood that what we then estimate are reduced form equations, but as such they can in some cases be interpreted as causal relationships because it is safe to assume that the nominal interest rate changes first and that the effects on real investment (if any) comes after.

Two final empirical models will be presented. The difference lies in how the trend component is incorporated in the GUM. The deterministic trends appear as regressors with LHPI as the

dependent variable, whereas the hp- trend will be subtracted from LHPI and the new endogenous variable LHPIhp created. As was apparent from figure 6.5, the effect on the investment rate of increases in the FEDFUNDS is highly affected by the initial level of the FEDFUNDS. In order to represent this, the explanatory variables in our model will be the FEDFUNDS, the inverse of FEDFUNDS (INVFEDEFUNDS), and the inverse of the squared of the FEDFUNDS (INVsqFEDEFUNDS). Hence, the functional form is non-linear.

In the initial GUMs, 8 lags of each variable have been included. In addition, for the hp trend, it is important to make explicit that the constant has been fixed prior to allowing *Autometrics* to delete variables, in order to ensure that it is retained throughout the selection process and gives a final model with desirable long- run properties. After the final model has been estimated, it has been tested for significant outliers, also performed by *Autometrics* (by the method of large outliers). The two models, one for each trend, then obtained, are reported in table 6.2. Note that all the diagnostic tests at the bottom of the table are insignificant at the 1 % and all but one at the 5 % level. This is important for doing valid tests of significance by use of the t- and F-statistics for example.

The first thing that appears from table 6.2 is that *Autometrics* has found significant outliers in the final models, regardless of trend. Hence for these periods there have been changes in housing prices that cannot be explained by changes in the explanatory variables included in our model. More specifically, the fluctuations in housing prices at these points in time cannot be explained by fluctuations in their lags or the FEDFUNDS. For instance, the negative coefficients of the significant outlier found for the 3rd quarter in 2008 suggest that there was a reduction in housing prices beyond those accounted for by changes in the FEDFUNDS. With reference to the theoretical discussion, such sharp changes in the price of a capital good may very well occur after a period when the price has been increasing as a result of widespread beliefs in the market about high returns on this type of investment. Initially, those beliefs may have been based on low loan interest rates and little or no response in the policy interest rates to the rise in house prices. In this way the fuel and mechanism of booms and busts may have been installed. Hence, for the outlier in our case there simply might have been a burst of a bubble that the Fed could not have prevented at that time in history.

In figure 6.5 and 6.6 the dynamic multipliers for the deterministic and the stochastic trends are illustrated, for three different initial levels of the FEDFUNDS. Because of the functional

Table 6.2: Estimation results for the models chosen by *Autometrics*, housing prices.

	Endogenous variable: LHPI		Endogenous variable: LHPIhp	
Regressor	Coefficient	t-value	Coefficient	t-value
Constant	0.1470***	5.90	-0.0013	-0.415
LHPI(t-1)	0.9824***	21.0	-	-
LHPI(t-3)	0.2337**	3.13	-	-
LHPI(t-5)	-0.2698***	-6.31	-	-
LHPIhp(t-1)	-	-	0.8078***	17.9
LHPIhp(t-3)	-	-	0.1821**	2.87
LHPIhp(t-5)	-	-	-0.1711***	-3.69
FEDFUNDS(t-2)	-	-	0.0011***	3.41
FEDFUNDS(t-4)	-0.0020**	-3.31	-0.0008*	-2.10
FEDFUNDS(t-5)	0.0027***	4.37	-	-
INVFEDFUNDS(t-5)	-	-	-0.0522**	-2.62
INVFEDFUNDS(t-6)	0.0269***	5.46	0.0445***	3.97
INVsqFEDFUNDS(t-2)	-0.0005***	-3.86	-0.0005***	-3.48
INVsqFEDFUNDS(t-5)	-	-	0.0205*	2.56
t	0.0006***	4.45	-	-
I: 1977(4)	0.0197**	2.95	0.0166**	3.09
I: 1979(1)	0.0220**	3.33	0.0227***	4.30
I: 1981(4)	-	-	-0.0302***	-5.17
I: 1982(3)	-0.0282*	-3.90	-0.0252***	-4.26
I: 1984(4)	-	-	-0.0149**	-2.81
I: 2008(3)	-0.0194**	-2.94	-0.0186***	-3.45
Diagnostic tests				
AR 1-5 test	F(5,115) = 0.43578		F(5,112) = 0.48597	
ARCH 1-4 test	F(4,125) = 0.49633		F(4,125) = 0.78599	
Normality test	Chi^2(2) = 0.27857		Chi^2(2) = 0.24654	
Hetero test	F(16,112) = 1.7610*		F(17,109) = 1.4857	
Hetero X-test	F(44,84) = 1.2303		F(53,73) = 1.2801	
RESET 23 test	F(2,118) = 0.31313		F(2,115) = 0.085199	
Other				
No. of observations	133 [1977(1)-2010(1)]		133 [1977(1)-2010(1)]	
R ²	0.999819		0.954233	
$\hat{\sigma}$	0.00638454		0.00517259	

* p<0.05, **p< 0.01, ***p<0.001

form, these are not available from PcGive, but have been calculated manually and I have used Excel to find the numerical values for the different multipliers. Notice that the multipliers reported are those of a temporary change in the FEDFUNDS.¹⁹ Further, for all the figures in which dynamic multipliers are illustrated the number of quarters after the initial change is measured along the x-axis. Taken at face value, figure 6.6 implies that the market has been “speculative” all the time, which seems unlikely even for the US. Having a closer look at figure 6.3, the dynamic multipliers obtained from the determinist trend would have given a

¹⁹ The change in the FEDFUNDS is one of one percentage point (1 %) both in this case and in the case for nonresidential fixed investment (considered in the next section), and for both the temporary and permanent case.

similar picture, had the cubic trend been used, that is if t , t^2 and t^3 all had been included in the final model. However, they were not, which suggests that we should rely on the results obtained from the econometric model with the deterministic trend, and this is exactly what will be done in the rest of this section.

As can be seen from figure 6.6, the effects of a temporary change in the FEDFUNDS are very small (in absolute value), at most about -0.5 percentage point, and that is for a low initial level of the FEDFUNDS, when the effect is expected to be the largest. However, when there is a permanent change in the FEDFUND, the effects might be substantial. For instance, for an initial value of the FEDFUNDS of 0.25 percentage points a permanent marginal increase could be approximated (by looking at the relevant graph of figure 6.6) to be -5 percentage points 25 quarter after the increase. Hence, from the considerations of the dynamic multipliers we are lead to conclude that: Housing prices are affected, but not easily controlled, by changes in the FEDFUNDS.

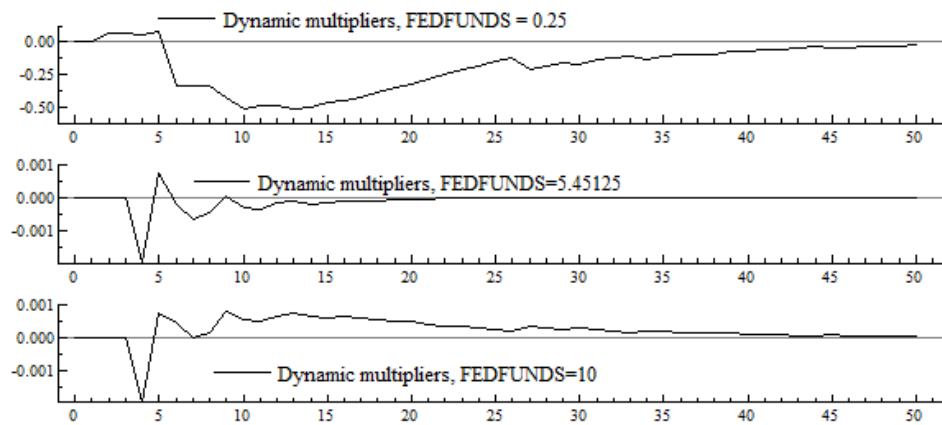


Figure 6.6: Temporary change in the FEDFUNDS, effect on LHPI, deterministic trend.

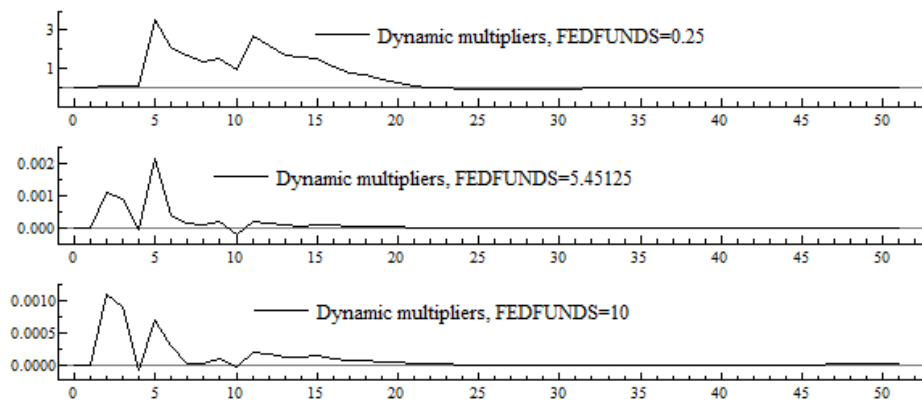


Figure 6.7: Temporary change in the FEDFUNDS, effect on LHPIhp, hp-trend.

From the estimation results in table 6.2, the high R^2 indicates that we are able to explain close to all the fluctuations in the log of housing prices by fluctuation in their lags and the FEDFUNDS (for the deterministic trend also the trend component will serve as an explanatory variable). However, this may be misleading, which will be shown in the following. For the deterministic trend, introduce DLHPI as the dependent variables, that is, subtract the first lag of LHPI on both sides of the estimated equation. The model then obtained will be statistically equivalent to that reported in table 6.2, which is confirmed by the exact same value of the estimated residual standard error (not reported). We will only present the graph with the actual value of DLHPI against its fitted counterpart, appearing in figure 6.8. From the figure we can see that our model seems to explain the really big booms and busts in housing prices, but not all the fluctuations, off course, as it is rather simplistic. Just for it to be mentioned, in this model the value of R^2 is 0.76.

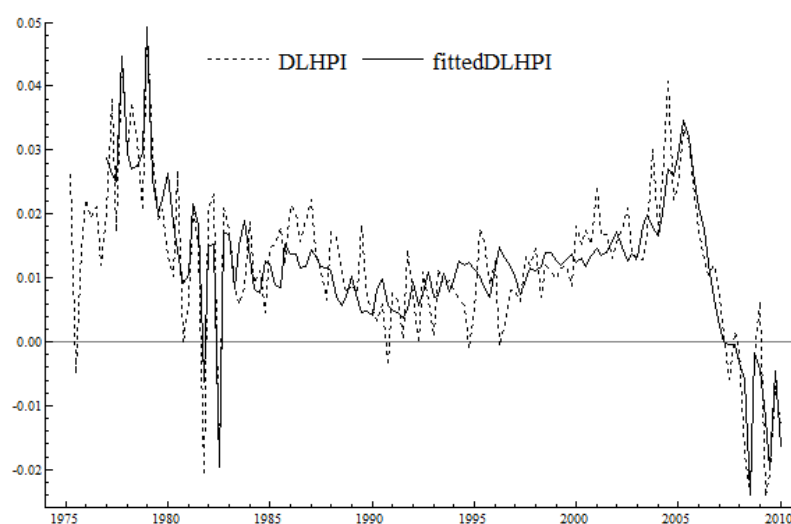


Figure 6.8: Actual value of DLHPI against its fitted counterpart.

6.4 Private nonresidential fixed investment

As for the residential investment, the crucial variable for private nonresidential investment will be the expected real rate of return. Whenever the FEDFUNDS is low, borrowing costs will be low. Then, two things might happen. With low borrowing costs, investment will be made possible for more people and thus their investment could increase. On the other hand, a lower FEDFUNDS may also be expected to lead to a decrease in the future price of real capital, making investment less attractive. Hence, we expect the FEDFUNDS to affect the investment, but are uncertain about the sign of the effect.

Further, it is important to note that the effect may be time dependent: When the FEDFUNDS is low at the same time as the real rate of return on productive capital is low, there may be little investment activity in spite of the low borrowing costs. This can be the case in a depression when there is idle capacity and many investors seek a safe haven rather than risk investing in production facilities that after all do depend on demand to repay even the lowest of borrowing costs. At the other extreme: Even a very high interest rate may not be enough to curb keen investors in a period of boom. Hence, even though there is a functional relationship between interest rates and investments, that function is probably not linear and can also shift over time, as indicated. For what its worth, this is the main implication of Haavelmo's theorizing in his field. No doubt it is nihilistic, but at least it warns against oversimplifications.

To access the correct information on the investment activity, the level of investment has to be seen in light of the overall economic activity, as measured by the gross domestic product (GDP). Accordingly, the variable considered in this section will be the rate of private nonresidential fixed investment, that is, the size of private nonresidential fixed investment relative to the size of the GDP, and will be referred to as the investment rate.

For housing prices we saw that there were significant correlation coefficients for the 20 first lags, but that they were diminishing (in absolute value that is). For the investment rate however, as is evident from figure 6.9, the cross correlation coefficients are not significant until after some 25 quarters, at which point they are positive. There may be many reasons for this, but one can certainly be closely related to the theoretical model presented in chapter 2. Knowing that the interest rate has been controlled by the Fed during our sample period, our theoretical model suggests that booms and busts are likely to occur. Figure 6.9 seems to support this as the investment rate today appears to be affected by the FEDFUNDS almost eight and a half years back, which sets it off on a boom that seems not to be significantly affected by future levels of the FEDFUNDS.

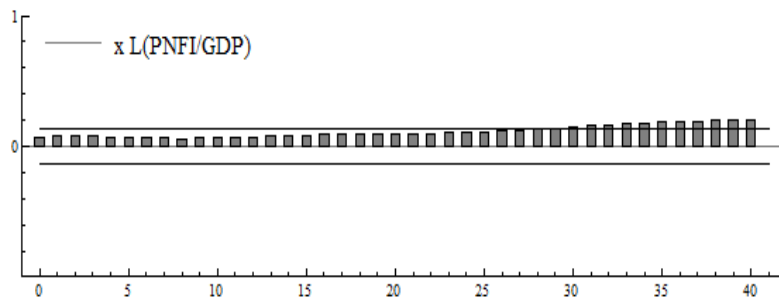


Figure 6.9: Cross correlation function between $L(PNFI/GDP)$ and the FEDFUNDS.

We would expect the effect of the FEDFUNDS on the investment rate to depend on the initial level of the FEDFUNDS, which seems to be confirmed by figure 6.10. It is a scatter plot of the FEDFUNDS and the log of the investment rate, $L(PNFI/GDP)$, including 10 sequential regression lines. However, as the initial level of the FEDFUNDS increases, the effect of it increasing becomes less significant, and in some cases even changes sign. In particular, for high levels of the FEDFUNDS, there seems to be a positive but rather small effect on the investment rate of changes in the FEDFUNDS. This suggests that the effect on the investment rate of increases in the FEDFUNDS is highly affected by the initial level of the FEDFUNDS, and this will set the premise for the inclusion of variables in the GUM presented next.

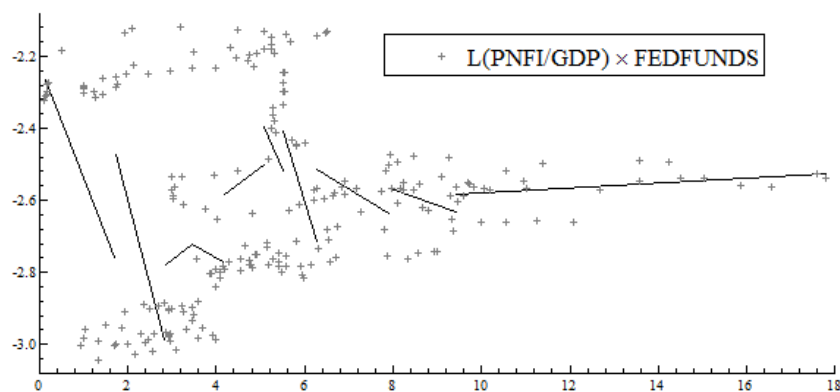


Figure 6.10: Scatter plot of the FEDFUNDS and $L(PNFI/GDP)$, with regression lines.

For the econometric model, we specify a GUM with 8 lags of the dependent variable and all the explanatory variables, which are identical to those included in the GUM for housing prices. First a final model is tracked down, and thereafter tested for significant outliers, both at 5% significance level. The models then obtained, one for each trend, are reported in table 6.3. Also in this case Autometrics has been instructed to keep the constant throughout the deletion process for the hp-trend, in order for the final model to have desirable long-run properties.

As already stated, the appearance of significant outliers in the final model indicates that there will be some effects on the investment rate that the changes in the FEDFUNDS are not able to explain. For instance, for the 4th quarter of 1981 a significant outlier with a positive coefficient appears, regardless of the choice of trend. Knowing that the FEDFUNDS fell by about three percentage point (from a level of about 17%) compared to the preceding quarter, our model predicts that there should be a negligible increase in the investment rate, but the existence of the outlier suggests that it increases by more than what the change in the FEDFUNDS can account for. With reference to our theoretical model: the fall in the FEDFUNDS has made capital superior to financial assets, and everyone will start investing in real capital, its real rate of return will increase, and its marginal product decrease. A bubble will be created, which could be reflected by the positive outlier detected.

Table 6.3: Estimation results for the models selected by *Autometrics*, investment rate.

	Endogenous variable: L(PNFI/GDP)		Endogenous variable: L(PNFI/GDP)hp	
Regressor	Coefficient	t-value	Coefficient	t-value
Constant	-0.1381**	-2.74	0.0079*	2.29
L(PNFI/GDP)hp(t-1)	-	-	0.9459***	36.1
L(PNFI/GDP)hp(t-5)	-	-	-0.1326***	-4.59
L(PNFI/GDP)(t-1)	1.0674***	44.2	-	-
L(PNFI/GDP)(t-5)	-0.1171***	-5.04	-	-
FEDFUNDS(t)	0.0040***	6.20	0.0038***	6.79
FEDFUNDS(t-3)	-0.0065***	-8.88	-0.0044***	-7.32
FEDFUNDS(t-8)	0.0025***	4.97	-	-
INVFEDFUNDS(t)	-0.0389***	-7.10	-0.0183***	-6.25
INVFEDFUNDS(t-1)	0.0197***	6.65	0.0202***	6.35
INVFEDFUNDS(t-6)	-	-	-0.0173**	-2.82
INVsqFEDFUNDS(t)	0.0024***	3.79	-	-
t3	2.13400e-009**	3.14	-	-
I: 1968(2)	-0.0471**	-3.34	-0.0473***	-3.54
I: 1980(2)	-	-	-0.0354**	-2.63
I: 1980(3)	0.0407**	2.83	-	-
I: 1981(4)	0.0551**	3.80	0.0513***	3.73
Diagnostic tests				
AR 1-5 test	F(5,198) = 0.62575		F(5,200) = 0.47282	
ARCH 1-4 test	F(4,208) = 0.88286		F(4,208) = 1.1662	
Normality test	Chi^2(2) = 3.5960		Chi^2(2) = 3.2875	
Hetero test	F(17,195) = 0.50996		F(14,198) = 0.88907	
Hetero X-test	F(51,161) = 1.4921*		F(34,178) = 1.1987	
RESET 23 test	F(2,201) = 0.084023		F(2,203) = 3.7210*	
Other				
No. of observations	216[1956(3)-2010(2)]		216[1956(3)-2010(3)]	
R²	0.997164		0.897164	
σ̂	0.0139539		0.013231	

*p<0.05, **p<0.01, ***p<0.001

The fact that some of the explanatory variables are included in the final model is definitely a sign of a relationship between interest rates and the investment rate. However, notice the low

absolute values of the coefficients, which indicate that the effect is rather small. Still, a conclusion can not be drawn before having a closer look at the dynamic multipliers. Once again the multipliers considered are for temporary changes in the FEDFUNDS, and are illustrated in figure 6.11 and figure 6.12, one for each trend. To obtain these multipliers, the same procedure as for housing prices is used.

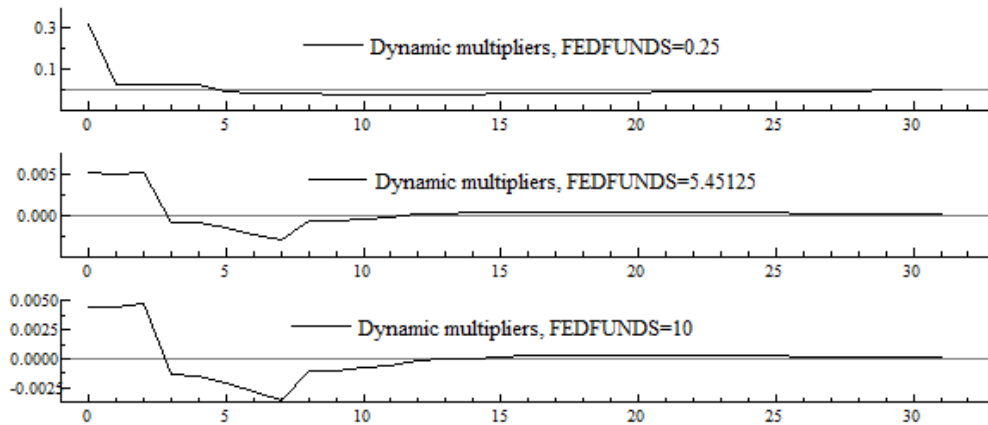


Figure 6.11: Temporary change in the FEDFUNDS, effect on $L(PNFI/GDP)$, determ. trend.

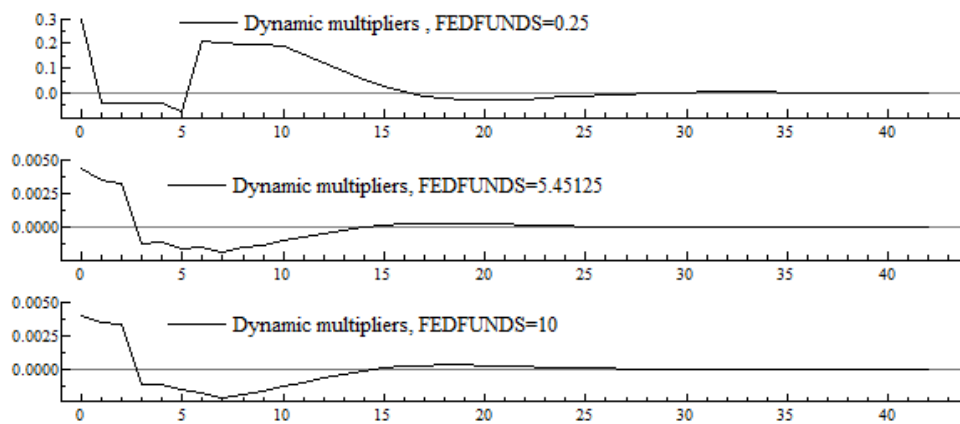


Figure 6.12: Temporary change in the FEDFUNDS, effect on $L(PNFI/GDP)_{hp}$, hp -trend.

Note that in this case, as opposed to the case for housing prices, there seems to be larger compliance on the numerical size of dynamic multipliers across trends. Further, it seems as if the effects of a temporary change in the FEDFUNDS on the investment rate are rather modest, in this case even more so than for housing prices as the strongest effect appears to be some 0.3 percentage points, and that for a low initial FEDFUNDS level. Now, for a permanent marginal increase in the FEDFUNDS, the effects could differ substantially. In particular, for an initial level of the FEDFUND of 0.25 percentage points, a marginal

permanent increase will result in an increase of about 0.3 percentage points with the deterministic trend, but about 1.5 percentage points for the hp-trend. For larger initial levels of the FEDFUNDS, the effects are similar across trends. Thus, from our estimation results the following conclusion appears: The investment rate is modestly affected, and even less so able to control, by changes in the FEDFUNDS.

Whenever the Fed adjusts its target for the federal funds rate in order to promote a high level of employment and low and stable inflation, our theoretical model predicts that the real rate of return to capital might be different from its marginal product, sending the economy into either a boom or bust. In particular, a reduction in the target for the federal funds rate may lead to a situation in which the marginal product of real capital is higher than its real rate of return. Such a situation will make real capital very attractive for producers, and thus their willingness to pay for it will increase substantially. Consequently, real capital will become an attractive asset to invest in, and the stock of real capital will increase, which will lead to a reduction in its marginal product. The occurrence of a bubble in the market for real capital appears evident: Its price is ever increasing regardless of the reduction in its marginal product. This short analysis suggests that when bubbles are first created, temporary changes in interest rates will hardly affect them, which seems to be confirmed by our estimation results, both for the investment rate and housing prices.

7 Conclusion

Haavelmo's model stands out from mainstream macroeconomic theories. The theory's main implication, that the interest rate is not a "free" instruments variable for exchange rate or inflation targeting, unless one is prepared to forsake balance in asset markets, does not all go down well with the mainstream view that holds the exact opposite. In particular, the model suggests that there is no certainty about the high correlation between investment activity and interest rates, and more so that it will depend on the conduct of monetary policy in a very complicated way, much more so than what is attempted described herein. However, despite our simple approach, we have found that it is possible to interpret recent events in light of Haavelmo's framework. For example, it appears from our results that both housing prices and the investment rate are hard to control by means of moderate changes in interest rates, on U.S data.

There is another interpretation of our finding off course: The empirical models may be said to be too loosely specified, and that their failure to capture a strong effect from interest rates to investments simply reflects that. Hence they cannot be interpreted as saying anything about whether Haavelmo had a valid point or not. I think that the verdict is still open and that more work needs to be done. What we have been reminded of though, is that economic stabilization through monetary policy needs a broad reference framework in which, in particular, the general (dis)equilibrium implications of interest rate setting need to be taken seriously.

References

- Bårdsen G. and R. Nymoen (2001): “Rente og inflasjon”, Norsk økonomisk tidsskrift, No.2, 125-146.
- Bårdsen G. and R. Nymoen (forthcoming, 2011): “Økonometri”, Fagbokforlaget.
- Carter Hill, R., W.E.Griffiths, G.C. Lim (2008): Principles of Econometrics, 3rd edition, John Wiley & Sons inc., USA.
- Doornik, J.A (2009): An introduction to OxMetrics™ 6: A Software System for Data Analysis and Forecasting, Timberlake Consultants Ltd, London.
- Doornik, J.A, and D.F. Hendry (2009): Empirical Econometrics Modelling- PcGive™ 13: Volume I, Timberlake Consultants Ltd, London.
- Ericsson, N. R.(2010): ”Empirical model selection: Freidman and Schwarz revisited”, downloaded from <http://www.gwu.edu/~forcpgm/NeilEricsson-FSGets-March2010.pdf>, on 20.10.10.
- Haavelmo, T. (1969): Orientering i makroøkonomisk teori, Universitetsforlaget, Oslo.
- Haavelmo, T. (1987): “Pengepolitikken i et “fritt” kredittmarked”, arbeidsnotat 87/9, Norges Bank.
- Kennedy, P. (2008): A Guide to Econometrics, 6th edition, Blackwell Publishing, Malden.
- Reinhart, C.M., and K.S. Rogoff (2008): “ Is the 2007 U.S Subprime Crisis So Different? An International Historical comparison”, American Economic Review, 2:98, 339-344.
- Rødseth, A. (2000): “Open economy macroeconomics”, Cambridge University Press, Cambridge.
- Sørensen P.B and H.J. Whitta – Jacobsen (2005): “Introducing Advanced macroeconomics: Growth and Business Cycles”, McGraw-Hill Education, Berkshire.

Appendix A: Documentation of data

The following gives definitions and names of the variables used in the econometric analysis and the graphs presented. Each entry starts with a heading, in boldface, with a descriptive name and a parenthesis with the name the variable has in the data file. Then follows a closer description of the variable (units of measurement and other information), and finally, sources are listed.

Federal funds effective rate (FEDFUNDS)

The percentage interest rate that the borrowing bank pays to the lending bank to borrow funds is negotiated between the two banks, and the weighted average of this rate across all such transactions is the federal funds effective rate. It is calculated by the Federal Reserve Bank of New York using data provided by brokers. The source reports this variable at monthly rates, but for our purpose it has been transformed to quarterly rates. Since the FEDFUNDS is a stock variable, the quarterly rate appears as the average of the three relevant months. Not seasonally adjusted (NSA).

Sources: Federal Reserve Bank of St. Louis FRED database at <http://research.stlouisfed.org/fred2/series/FEDFUNDS> , downloaded on 06.09.2010

Gross domestic product (GDP)

The gross domestic product is the market value of final goods and services produced within a nation's (in our case the USA) borders during a fixed period of time. This variable is reported at quarterly rates in billions of chained 2005 dollars. Seasonally adjusted (SA).

Source: Bureau of Economic analysis at <http://www.bea.gov/national/index.htm#gdp> under the heading Current-dollar and "real" GDP, downloaded on 23.09.2010.

House price index (HPI)

As defined by the Federal Housing Finance Agency (FHFA): The HPI is a broad measure of the movement of single-family house prices. The HPI is a weighted, repeat-sales index, meaning that it measures average price changes in repeat sales or refinancings on the same properties. The national-level HPI considered in our case was created by finding the

arithmetic mean of those in the 50 U.S. States and the District of Columbia. The base year is 1980, in which case the index is 100. The data are quarterly. NSA.

Source: Author's calculations based on data for each state and the District of Columbia from Federal Reserve Bank of St. Louis FRED database at <http://research.stlouisfed.org/fred2/search?st=HPI&pageID=2> , downloaded on 07.09.2010.

Private nonresidential fixed investment (PNFI)

Private nonresidential fixed investment consists of purchases of both nonresidential structures and equipment and software. This variable is reported at quarterly rates in billions of chained 2005 dollars. SA.

Sources: Author's calculations based on data for SA current-dollar PNFI and the SA "PNFI price index" (with 2005 as base year in which case the index is 100) from the Federal Reserve Bank of St. Louis FRED database, respectively at <http://research.stlouisfed.org/fred2/series/PNFI>, downloaded on 07.09.2010, and <http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=4&ViewSeries=NO&Java=no&Request3Place=N&3Place=N&FromView=YES&Freq=Qtr&FirstYear=1947&LastYear=2010&3Place=N&Update=Update&JavaBox=no> (row 9 in the table), downloaded on 23.09.2010

A few words on the calculations. Let us first introduce the following variables:

PNFI= the variable used in our analyses, reported in billions of chained 2005 dollars

PNFIC= private fixed investment reported in current dollars

PNFIPI=private fixed investment price index.

The formula used is then, for each quarter q of each year y

$$PNFI_{y(q)} = \frac{PNFIC_{y(q)} * 100}{PNFIPI_{y(q)}}, \quad y(q) = 1947(1), 1947(2), 1947(3), \dots, 2010(2)$$

CPI (consumer price index)

As defined by the Bureau of Labor Statistic, the CPI is a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services. The source reports this variable at monthly rates, but has been transformed to quarterly rates accounting for the fact that it is a stock variable. The average index level (representing the average price level) for the 36-month period covering the years 1982, 1983, and 1984 is set equal to 100. SA.

The percentage CPI annual inflation rate is calculated by use of the following formula:

$$INF_{y(q)} = \frac{(CPI_{y(q)} - CPI_{y(q-4)}) * 100}{CPI_{y(q)}}, \quad y(q) = 1947(1), 1947(2), \dots, 2010(2)$$

where y denotes the year and q the quarter Source: Federal Reserve Bank of St. Louis database FRED at <http://research.stlouisfed.org/fred2/series/CPIAUCSL>, downloaded on 10.11.2010.

Appendix B: Explanation of trends and diagnostic tests

Most economic time series fluctuate around a time trend, and it is therefore convenient to decompose time series variables into a cyclical and a trend component. An exposition presented in Sørensen and Whitta-Jacobsen (2005) will prove useful in the following:

If Y_t is a time series variable (of which an example may be real GDP), it is convenient to think of it as the product of a growth component Y_t^τ , indicating the trend value which Y_t would assume if the economy was always on its long-term growth path, and a cyclical component Y_t^c which fluctuates around a long-run mean value of 1 (hence $Y_t = Y_t^\tau$ on average):

$$(B.1) \quad Y_t = Y_t^\tau * Y_t^c$$

Recall that the change in the natural logarithm of some variable is approximately equal to the percentage change in the variable itself. Taking log on both sides of the above equation and defining the variables $y_t = \ln(Y_t)$, $\tau_t = \ln(Y_t^\tau)$ and $c_t = \ln(Y_t^c)$, we get:

$$(B.2) \quad y_t = \tau_t + c_t$$

We will be able to observe the actual values of time series variables, but a completely objective method of separating the trend from the cyclical component does not exist. In our case this separation has been attempted performed by using four different trends, to which a brief introduction follows next.

THE HODRICK PRESCOTT FILTER

The Hodrick- Prescott filter has room for variations in the underlying trend component, but at the same time makes sure that short-term fluctuations are characterized as temporary cyclical deviations from trend. In particular, it suggests that the trend component, τ_t , be determined by solving the following problem:

$$\min_{\tau_t} \sum_{t=1}^T (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} [(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2$$

where λ is chosen by the observer (for US quarterly GDP - data it is customary to set $\lambda = 1600$). Recalling that y_t is measured in logarithms the term in the square bracket in the above stated minimization problem is the approximate growth rate of the trend component from period t to period $t+1$, while the term $y_t - \tau_t$ is the cyclical component of the variable in period t . Then it becomes evident that the Hodrick Prescott filter introduces a tradeoff between minimizing fluctuations in the cyclical component and the trend component. The relative weight given to each objective will depend on the choice of λ , of which a higher value indicates a greater degree of aversion to fluctuations in the trend component.

THE DETERMINISTIC TRENDS

All of these trends postulate that the trend component of any time series would grow at a constant rate. The trend component of the time series is found by regressing it on the relevant deterministic trend and storing the fitted values, as these will give us the level of the time series explained by fluctuations in the trend component. In particular, the linear trend component of the natural logarithm (following notation) of a time series, y_t , is found by the following procedure:

1. Estimate the model:

$$y_t = \alpha_0 + \beta_1 t + u_t$$

2. Store the fitted values, which will be our estimate of the trend component; $\hat{\tau}_t$

To find the square and the cubic trend component the models to be estimated are, respectively

$$y_t = \alpha_0 + \beta_1 t + \beta_2 t^2 + \varepsilon_t$$

$$y_t = \alpha_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \varepsilon_t$$

Again, to find the estimated trend component, store the fitted values.

Next follows a simple verbal explanation of each of the diagnostic tests reported for each estimated model, based on those found in Doornik and Hendry (2009), Griffiths, Hill and Lim (2008), and Bårdsen and Nymoen (forthcoming, 2011).

ERROR AUTOCORRELATION TEST (AR-TEST)

This test is based on an auxiliary regression of the estimated residuals from the original regression on their r -lags (in our case 5) and all the regressors in the initial model. The null of all of the coefficients of the lagged residuals being zero is tested against the alternative that either is different from zero, indicating that the residuals are auto correlated.

AUTOREGRESSIVE CONDITIONAL HETEROSCEDASTICITY TEST (ARCH-TEST)

To perform this test it is necessary to first estimate the mean equation, which is a regression of the dependent variable on a constant. Then the estimated residuals \hat{e}_t are saved and their squares \hat{e}_t^2 obtained. To test for r -order ARCH, \hat{e}_t^2 is regressed on r lags of the squared residuals and the null hypothesis of all of the coefficients being 0 is tested against the alternative that either is different from 0.

NORMALITY TEST

The null hypothesis of normally distributed residuals is tested against the alternative that they are not. Note that the test reported in this case is not the usual LM test by Jarque and Bera. For an explanation of the relevant test statistic, see Doornik and Hendry (2009), section 18.4.4.

HETEROSCEDASTICITY TEST USING ONLY SQUARES (HETERO TEST)

An auxiliary regression of the squared of the residuals on the original regressors and all their squares is estimated. The null hypothesis of all these coefficients being 0, implying homoscedasticity, is tested against the alternative that at least one is different from zero, implying heteroskedasticity.

HETEROSCEDASTICITY TEST USING SQUARES AND CROSS PRODUCTS (HETERO-X TEST)

This test is calculated only in cases where there is a large number of observations relative to the number of variables in the regression. It is based on an auxiliary regression of the squared residuals on all squares and cross products of all the regressors included in the original regression. The null hypothesis of all their coefficients being zero is tested against the alternative that either is different from 0, implying heteroscedasticity.

REGRESSION SPECIFICATION TEST USING SQUARES AND CUBES (RESET23 TEST)

This test helps us detect omitted variables and incorrect functional forms. It is based on an auxiliary regression of the dependent variable on all the regressors included in the original regression in addition to the squared and cubed fitted values from that regression. We test the null of no misspecification, implying that both of the coefficients for the squared or cubic values are zero, against the alternative that at least one is different from zero.